# **Chapter III: Environmental Impact**

#### A. Inventory Impacts of Tier 2/Sulfur

Today's action will reduce NOx, VOC, particulate, SOx, carbon monoxide, and hazardous air pollutant emissions from cars and light trucks by lowering the VOC, NOx, and PM emission standards for these vehicles and requiring that gasoline sulfur levels be reduced. Over time, the projected benefits of today's action will grow as vehicles meeting the new standards replace older, higher-emitting vehicles and as total VMT continues to grow. The results of our analysis of light-duty inventory levels with and without today's action are presented and discussed for each pollutant in the following sections. In all cases, "without Tier 2/Sulfur" refers to continuation of National LEV for LDVs and LDTs under 6000 pounds and Tier 1 for LDTs above 6000 pounds on in-use fuel as currently specified; sulfur levels for Conventional Gasoline are estimated at 330 ppm<sup>1</sup>, summertime Phase 2 RFG levels are estimated at 150 ppm (i.e., baseline case). "With Tier 2/Sulfur" refers to implementation of 120 ppm sulfur nationwide in 2004, 90 ppm in 2005 and 30 ppm in 2006 in conjunction with the phase-in of NOx, VOC, and PM vehicles standards finalized under today's action (i.e., control case).<sup>2</sup>

For the proposal, separate emission inventories were used as the basis for the inventory projections, air quality analysis and cost-benefit analysis. The emission inventory estimates were based on updated estimates of on-highway mobile source emissions as planned for use in EPA's MOBILE6 model, using a spreadsheet program known as the Tier 2 Model. However, the air quality and cost-benefit analyses presented in the proposal were based on previous work which relied on both MOBILE5 and the Tier 2 model. This discrepancy has been reconciled for the final rule. Subsequent to the proposal, new emission inventories were generated for every county in the nation in 1996, 2007 and 2030. These inventories reflect the on-highway mobile source emission updates contained in the NPRM version of the Tier 2 Model, and were used as the basis

<sup>&</sup>lt;sup>1</sup>For NOx and VOC, the modeling performed in support of our air quality and cost-benefit analyses was based on a sulfur baseline of 330 ppm for conventional gasoline. This estimate has since been updated to 300 ppm, reflecting recent in-use fuel data and our expectation that refiners will shift sulfur to summertime conventional gasoline in order to meet the Phase 2 RFG NOx performance specification. This change has been incorporated into our updated Tier 2 Model, as detailed in a memorandum from John Koupal to Docket A-97-10 entitled "Development of Light-Duty Emission Inventory Estimates in the Final Rulemaking for Tier 2 and Sulfur Standards". Our PM and SOx estimates are based on PART5, which uses a sulfur level of 339 ppm for conventional gasoline.

<sup>&</sup>lt;sup>2</sup>These sulfur levels would occur under our Sulfur Averaging, Banking and Trading (ABT) program, for which reduced sulfur levels could occur as early as 2000. We did not include sulfur reductions prior to 2004 in our air quality analysis inventory estimates, but early sulfur reductions were accounted for in our updated Tier 2 Model.

for the inventory projections, air quality analysis and cost-benefit analysis (an updated version of the Tier 2 Model, which incorporates data and comments received subsequent to the proposal, is discussed below). Specifically, the modeling reflects updated assessments of in-use emission deterioration and off-cycle emissions, fuel sulfur impacts, and the increase in truck sales relative to cars. The modeling also reflects existing national and local motor vehicle control programs including National LEV (NLEV), Supplemental Federal Test Procedure (SFTP), On-Board Diagnostics (OBD), reformulated gasoline (RFG) and Inspection/Maintenance (I/M) programs. The final rule modeling also incorporates planned changes in emission rates for heavy-duty gasoline and diesel vehicles, as well as the effects of heavy-duty NOx defeat device.

The inventories generated from this round of modeling are presented as our "official" inventory estimates in this chapter; since they formed the basis of our final rule air quality analysis this work is referred to as the "air quality analysis" modeling, to distinguish from subsequent inventory modeling performed using updated inputs. These estimates of on-highway emissions were generated in several steps: First, MOBILE5 and PART5 where run for every county in the country. Next, multiplicative adjustment factors were applied to the output of MOBILE5 to account for changes planned for MOBILE6 for light-duty and heavy-duty vehicles; for 2007 and 2030, multiplicative adjustment factors were also developed which incorporated the benefits of the Tier 2/Sulfur program, for all pollutants. Finally, excess NOx emissions due to air conditioning usage were applied as a function of ambient temperature. This approach enabled a significant improvement over what was done in the proposal, in that the final rule inventories are estimated on a county-by-county basis using locally-specific modeling inputs and assumptions where available, "corrected" (for NOx and VOC) to our best estimate of MOBILE6 (at the time of the proposal) with and without Tier 2/Sulfur control. Thus the 47-state numbers presented here are not based just on national default inputs as was done for the proposal, but instead are based on the sum of the inventories for every county in the 47 states, including local average temperatures, fleet characteristics, I/M programs, fuel properties, and roadway type/speed distributions. Likewise, the city-specific inventories presented here, which are based on the same county-specific inventories, are substantially more accurate than the ones presented in the proposal, which are based on national default modeling input.

In the proposal, we used a combination of methods to project future highway vehicle miles traveled (VMT). The proposal approach used the 1997 National Emissions Trends (NET) Report VMT up to 2010, a compounded growth rate of 2.1 percent from 2010 to 2015 and a simple linear growth rate of 2.1 percent after 2015. For the final rule, we have chosen to project future growth using a linear extrapolation of the NET projections. This is a simpler, more consistent approach, which results in lower estimates of future VMT (a simple linear growth rate of 1.7 percent from 2007 to 2030). Total light-duty VMT estimates were split into light-duty vehicle (LDV), light-duty trucks below 6,000 pounds (LDT1/2) and light-duty trucks above 6,000 pounds (LDT3/4) using the methodology developed for the proposal, 2 accounting for the recent growth trends in LDT sales.

For the final rule, we have also updated the emission inventories for stationary, area, and nonroad sources. The development of inventories for all sources are provided in a separate document available in the Tier 2 docket.<sup>3</sup>

This section focuses on projections of the emissions inventory with and without today's action for the United States excluding California, Alaska, and Hawaii, derived from the final rule air quality analysis. Estimates from the final rule air quality analysis were also used to generate the relative contribution of light-duty vehicles and trucks to the total NOx and VOC inventories nationwide, as well as four urban areas: New York, Chicago, Atlanta and Charlotte. Comprehensive inventories (47-state and four city) are presented in Appendix A with and without Tier 2/sulfur control for 1996, 2007 and 2030, the three years for which the inventories were generated. For VOC and NOx, the nationwide inventories are presented as "annualized summer tons," meaning that inventory results for a typical July day were multiplied by 365 days. The purpose of this is solely to present a consistent comparison of emission trends and reductions based on summer conditions; the actual air quality and cost-benefit analyses relied on the seasonal inventories generated in the air quality analysis. Nationwide SOx and PM results presented in this section are true annual estimates.

For purposes of the analysis presented in this section, we also needed to estimate inventories in other years between 2007 and 2030. Estimates for light-duty vehicles and trucks in these intermediate years were derived from the NPRM version of the Tier 2 Model, adjusted to reflect differences in this model and the air quality analysis results.<sup>4</sup> To estimate stationary and area source inventories in other years, we did a simple linear interpolation of the 2007 and 2030 estimates. For nonroad and on-highway inventories, we know that the emissions inventory is non-linear between those years due to fleet turnover. To estimate intervening years, we first calculated the ratio of the air quality analysis nonroad and on-highway inventories in 2007 and 2030 to the inventories generated for the proposal for these sectors for those same years. Then we interpolated between the 2007 and 2030 ratios to estimate the ratio that we would expect in intervening years. We then multiplied those interpolated ratios by the NPRM inventories for those years. The result is an estimate of what the inventories would have been if we had done

<sup>&</sup>lt;sup>3</sup>The 47-state region comprised of the U.S. minus California, Alaska and Hawaii is interchangeably referred to as "nationwide" throughout this section. Although excluded from this analysis, emission reductions will be realized in each of these states. Today's action applies fully to Alaska, Hawaii, and U.S. territories; California, although subject to a separate vehicle and fuel control program, will benefit from lower-emitting Federal vehicles migrating to and/or traveling within the state, as well as California vehicles operating on cleaner non-California fuel.

<sup>&</sup>lt;sup>4</sup> In 2007, the 47-state annual VOC emissions reductions from the Tier 2/Sulfur program are approximately 13% larger than the annualized summer VOC emissions reductions (the smaller evaporative VOC emissions reductions in non-summer conditions are more than offset by higher exhaust VOC emissions reductions during colder weather), while the annual 47-state NOx emissions reductions are 6-7% smaller than the annualized NOx emissions reductions.

complete county-by-county inventories for them.

As mentioned, for the final rule air quality analysis the modeling assumptions and inputs for light-duty vehicles and trucks were identical to those included in the NPRM version of the Tier 2 Model. Subsequent to the air quality analysis modeling, our Tier 2 Model was updated to reflect several new inputs stemming from a) our response to Tier 2 comments, b) new sulfur sensitivity data and c) alignment with methodologies planned for use in MOBILE6, as well as changes to the sulfur control program.<sup>5</sup> Results from the updated Tier 2 Model are presented side-by-side with the air quality analysis inventory modeling results for VOC and NOx. The major updates to the model are summarized below:

- 1) Tier 1 and later NOx emission rates were updated to reflect a significantly larger sample of vehicles certified to the 0.4 gram/mile NOx standard, in response to comments.
- 2) Sulfur effects for LDV and LDT LEVs were increased significantly, in response to new data showing that the effect of sulfur on emissions is much larger when a vehicle operates on high sulfur fuel for a few thousand miles.
- The model incorporates the effects of sulfur irreversibility, which results when vehicles sustain permanent catalyst degradation from exposure to sulfur levels higher than what they typically operate on. Inventory estimates are presented for irreversibility levels consistent with those discussed in Appendix B.
- 4) The model incorporated the effects of representative in-use activity data planned for use in MOBILE6, including vehicle speed, roadway type, and trip activity.
- 5) The Tier 2/Sulfur control case reflects the sulfur program contained in today's action, as well as the effects of Averaging, Banking and Trading (ABT), interim provisions for small refiners, and the geographic phase-in of low sulfur fuel.

With these updates, the Tier 2 Model now includes many of the key exhaust elements planned for MOBILE6, and is the most up-to-date tool available for assessing trends in nationwide light-duty exhaust emissions and the emission reductions gained from the Tier 2/Sulfur program. Overall, the updated model indicates that NOx and exhaust VOC emissions without Tier 2/Sulfur control will be substantially higher than originally projected either in the proposal or by the air quality analysis modeling, particularly for NOx. Although the inventory estimates, air quality results and economic benefits assessment presented in this document show conclusively the need for and benefit of today's action, we believe based on the updated Tier 2 Model that the estimates of emissions reductions underlying these analyses are in fact very conservative.

#### 1. NOx

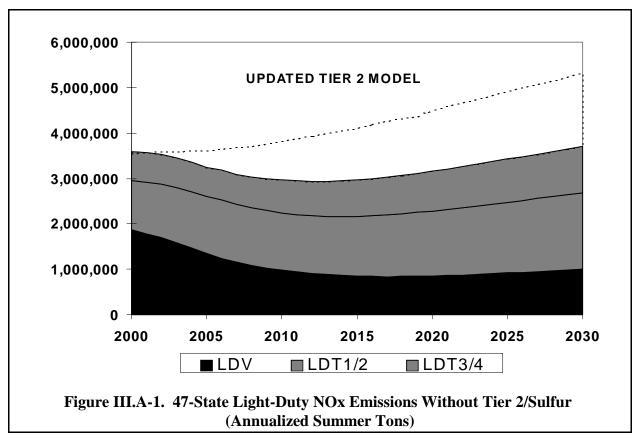
### a. Light-Duty NOx Trends Without Tier 2/Sulfur

Total NOx emissions produced annually in the 47 states by cars and trucks without Tier 2/Sulfur controls are shown in Table III.A-1 and Figure III.A-1, broken down by relative contribution of cars (light-duty vehicles, or LDVs), LDT1s and 2s (light pickup trucks, minivans and most sport utility vehicles), and LDT3s and 4s (heavier pickup trucks and sport utility vehicles). As mentioned, the air quality analysis inventory results are based on annualized summer day results in 2007 and 2030, with intermediate years developed based on the NPRM version of the Tier 2 Model. As shown, the estimates derived from the air quality analysis modeling show total light-duty emissions declining from approximately 3.6 million tons to 3.0 million tons between 2000 and 2010 due to turnover of Tier 1 and NLEV vehicles and the phase in of off-cycle standards (SFTP). By 2014, however, the effect of these control programs begins to be offset by increases in overall VMT, in conjunction with the shift of VMT from cars to trucks. Light-duty emissions increase to 3.2 million tons by 2020 and 3.7 million tons by 2030, such that the gains from the Tier 1, NLEV and SFTP control programs are more than offset by VMT growth.

The estimates derived from the updated Tier 2 Model suggest a much more dire situation. While the updated modeling estimates are similar to the air quality analysis estimates in 2000, emissions are projected to rise steadily from this point; by 2030, emission are projected to increase 50 percent from the 2000 levels.

Table III.A-1. 47-State Light Duty NOx Emissions Without Tier 2/Sulfur (Annualized Summer Tons)

	Light-Duty Emissions: Air	Contribution by Vehicle Class			Light-Duty	
Year	Quality Analysis Modeling	LDV	LDT1/2	LDT3/4	Emissions: Updated Tier 2 Model	
2000	3,591,547	52.1%	30.0%	17.9%	3,548,883	
2004	3,362,528	43.5%	37.1%	19.4%	3,612,395	
2007	3,095,698	37.3%	41.0%	21.7%	3,681,990	
2010	2,962,093	33.0%	42.7%	24.3%	3,817,070	
2015	2,968,707	28.6%	44.3%	27.1%	4,116,074	
2020	3,160,155	26.9%	45.2%	27.8%	4,502,761	
2030	3,704,747	27.1%	45.5%	27.4%	5,323,860	



The impact of steady truck growth on overall light-duty NOx emissions is clearly demonstrated in the preceding figure. In 2000, we project that trucks will produce nearly 50 percent of overall NOx emissions. Over the next 30 years, trucks will grow to dominate light-duty NOx emissions due to the combined effects of sales migration, higher mileage accumulation rates, longer lifespan, and more relaxed emission standards relative to LDVs. By 2010, we project trucks will make up two-thirds of light-duty NOx emissions; by 2020, nearly three-quarters of all light-duty NOx emissions will be produced by trucks. As shown in Figure III.A-1, the decrease in overall light-duty emission levels estimated in the air quality analysis modeling is due solely to reductions in LDV emissions. The benefits from Tier 1, NLEV and SFTP are not as pronounced for trucks, and are offset almost immediately by growth in truck VMT. As a result, truck emissions are stable through 2010 and begin increasing steadily beyond this as VMT growth overtakes the gains from existing control programs. The updated Tier 2 Model shows that emission gains from these control programs are completely offset by high sulfur sensitivity for LEVs, VMT growth and the increased penetration of light-duty trucks.

Figures III.A-2 and III.A-3 show our projections of the contribution of light-duty vehicles and trucks to the total NOx inventory (i.e., NOx emissions from all sources, including stationary, area, nonroad) in the 47 states and in Atlanta based on the air quality analysis modeling for a typical ozone season day. Table III.A-2 shows this same contribution across all four cities from 2007 through 2030 based on the air quality analysis modeling, and for the 47 states based on the air quality analysis modeling and the updated Tier 2 Model. Across the 47 states, the air quality analysis modeling estimates that cars and trucks produce 16 percent of total emissions in 2007, growing to nearly one-fifth of total NOx emissions by 2030. The updated modeling projects a light-duty contribution of 19 percent in 2007, growing to one-quarter by 2030. In all cases, the relative contribution of cars and trucks to total NOx emissions is projected to grow steadily.

Light-duty NOx contribution in urban areas is generally higher than in the 47-state region because of the increased concentration of VMT, in conjunction with the decreased prevalence of significant NOx contributors which are largely in non-urban areas (primarily utilities and agricultural nonroad sources). We expect that this trend will be consistent across many high-ozone urban areas. Atlanta provides the most striking example of this; the air quality analysis modeling projects that 34 percent of all NOx emissions will be produced by cars and trucks in 2007, growing to 41 percent by 2030. <sup>5</sup> The light-duty contribution in New York and Charlotte

<sup>&</sup>lt;sup>5</sup>The air quality analysis modeling reflects a baseline sulfur level of 330 ppm for Atlanta, our estimate of national average conventional gasoline at the time of the proposal. Atlanta has recently implemented a summertime lower sulfur fuel program requiring 150 ppm fuel in 1999 and 30 ppm fuel in 2003; Georgia has submitted a SIP revision including this program and requested EPA's approval of a waiver of federal preemption and the SIP revision. Approval of the waiver and SIP revision is still pending.

are higher than the national estimates, while the contribution in Chicago is slightly less than the 47-state estimate. Based on the national results, our updates to the modeling would result in even larger contributions from cars and trucks in these cities, and in urban areas nationwide.

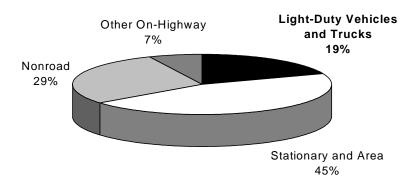


Figure III.A-2. Breakdown of Total 2030 47 State NOx Inventory Without Tier 2

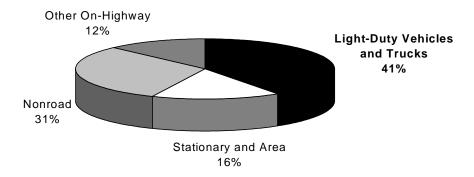


Figure III.A-3. Breakdown of Total 20209Atlanta NOx Inventory Without Tier 2

Table III.A-2. Light-Duty Contribution to Total NOx Inventory Without Tier 2/Sulfur (Typical Ozone Season Day)

V		Air Quality Analysis Modeling						
Year	47-State	47-State New York Chicago Atlanta		Charlotte	47-State			
2007	16%	18%	14%	34%	24%	19%		
2010	16%	-	-	-	-	20%		
2015	17%	-	-	-	-	22%		
2020	17%	-	-	-	-	23%		
2030	19%	22%	16%	41%	27%	25%		

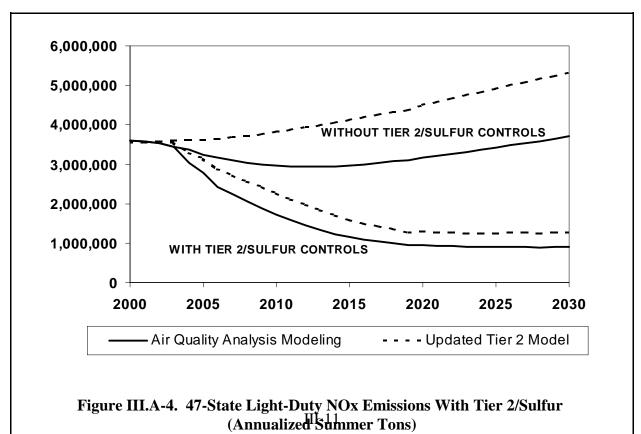
#### b. NOx Reductions Due To Tier 2/Sulfur

Today's action will provide substantial reductions in NOx emissions from cars and trucks. The implementation of low sulfur fuel will afford an immediate drop in NOx emissions, while the phase-in of tighter vehicle standards would continue to reduce emissions over time, serving to mitigate through 2028 the projected upward trend in light-duty NOx emissions that would occur with no control. Table III.A-3 contains annual tons of NOx we project will be reduced by today's action, encompassing benefits of low sulfur fuel and the introduction of Tier 2 light-duty vehicle and light-duty truck standards. Figure III.A-4 shows annual 47-state light-duty NOx emissions with implementation of the Tier 2/Sulfur program, broken down by LDV, LDT1/2 and LDT3/4 categories.

Table III.A-3. 47-State Light-Duty NOx Reductions Due To Tier 2/Sulfur (Annualized Summer Tons)

	Air Qual	lity Analysis N	10deling	Updated Tier 2 Model			
Year	Emissions	Percent Reduction Baseline Inventory		Emissions	Percent Reduction in Baseline Inventory		
	Reduced	Light-Duty	All Sources*	Reduced	Light-Duty	All Sources*	
2004	338,231	10%	-	326,556	9%	-	
2007	856,471	28%	5%	956,512	26%	5%	
2010	1,235,882	42%	7%	1,554,442	41%	8%	
2015	1,816,767	61%	10%	2,527,309	61%	13%	
2020	2,220,210	70%	12%	3,205,571	71%	16%	
2030	2,795,551	75%	15%	4,049,687	76%	20%	

<sup>\*</sup> Includes emission reductions from Heavy-Duty Gasoline Vehicles due to sulfur control



The projected reductions in 2004 are based on 120 ppm sulfur fuel, reflecting our final Tier 2 sulfur program. Our modeling shows an immediate benefit of over 300,000 tons in 2004, a 10 percent drop in uncontrolled light-duty emissions; this is the equivalent of emissions produced by 19 million pre-Tier 2 cars and trucks. In the early years of sulfur control, nearly all of the benefits would be due to reduced emissions from Tier 0, Tier 1 and NLEV vehicles. Although not shown, emission reductions due to sulfur control could be realized as early as 2000 under the sulfur ABT program.

After 2004, emissions are reduced further as the fleet turns over to predominantly Tier 2 vehicles operating on low sulfur fuel, versus NLEVs and Tier 1 trucks operating on current inuse sulfur levels. By 2020, the projected benefit represents a 70 percent reduction in 2020 light-duty emissions without Tier 2/Sulfur, equivalent to the emissions from nearly 164 million pre-Tier 2 cars and trucks. Total U.S. NOx emissions from all human sources would be reduced by 12 to 16 percent.

We project that light-duty emissions will continue to decrease beyond 2020, reversing the upward emissions trend in the baseline case brought on by VMT growth. By 2030, essentially the entire fleet will consist of Tier 2 vehicles. The benefit of 2.8 million tons projected by the air quality analysis modeling represents a three-quarters reduction in 2030 light-duty emissions without Tier 2/Sulfur, equivalent to the emissions from over 200 million pre-Tier 2 cars and trucks. These emission reductions are projected to be 15 percent of total NOx emissions in that year in the absence of today's action. The benefits projected by the updated modeling are even more substantial: emission reductions of over four million tons are projected, representing a 76 percent reduction of baseline light-duty emissions and a one-fifth reduction in NOx from all sources.

The estimated percentage reductions in total inventory presented in Table III.A-3 include benefits that will be realized from heavy-duty gasoline vehicles due to sulfur control. We estimate these heavy-duty emission reductions to be on the order of approximately 30,000 tons per year when 30 ppm fuel is in place. In addition, reductions from "Medium Duty Passenger Vehicles" (e.g. passenger vehicles above 8500 pounds included as part of Tier 2 vehicle program) are estimated to be approximately 37,000 tons in 2030.

Concurrently, we project that the light-duty contribution to total NOx emissions will drop significantly. Figures III.A-5 and III.A-6 show our 2030 projections of this contribution in the 47 states and in Atlanta with Tier 2/Sulfur control. Table III.A-4 shows this same contribution across the 47 states from 2007 through 2030, and in the four cities in 2007 and 2030. In 2030, the air quality analysis modeling projects that the light-duty contribution will drop to five percent

<sup>&</sup>lt;sup>8</sup>i.e., vehicles that would be on the road in the absence of Tier 2/Sulfur control.

nationally, from 19 percent without Tier 2/Sulfur control. This trend is similar across the four cities, depending on the level of contribution without Tier 2/Sulfur control. Based on the air quality analysis modeling we project that with Tier 2/Sulfur control, car and truck emissions would contribute six percent of total emissions in New York (down from 22 percent), four percent in Chicago (down from 16 percent), six percent in Charlotte (down from 27 percent), and 11 percent in Atlanta (down from 41 percent) in 2030.

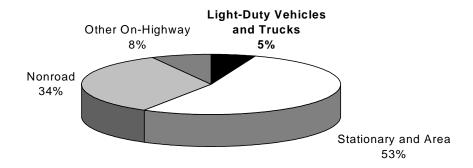


Figure III.A-5. Breakdown of Total 2030 47-State NOx Inventory With Tier 2/Sulfur

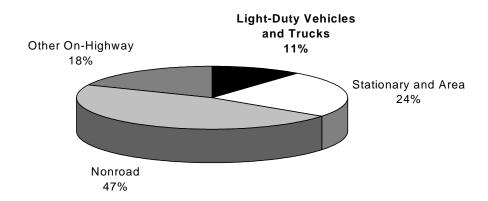


Figure III.A-6. Breakdown of Total 2030 Atlanta NOx Inventory With Tier 2/Sulfur

Table III.A-4. Light-Duty Contribution to Total NOx Inventory With Tier 2/Sulfur (Typical Ozone Season Day)

T.	Air Quality Analysis Modeling							
Year	47-State	New York	Chicago	Atlanta	Charlotte	47-State		
2007	12%	15%	11%	26%	18%	14%		
2010	10%	-	-	-	-	13%		
2015	7%	-	-	-	-	10%		
2020	6%	-	-	-	-	8%		
2030	5%	6%	4%	11%	6%	8%		

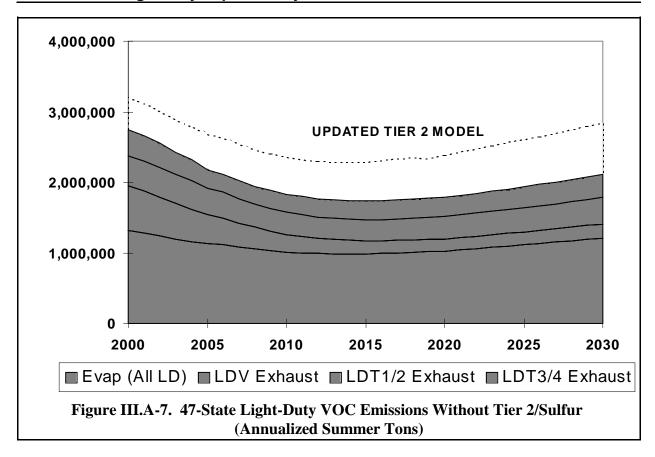
### 2. VOC

## a. Light-Duty VOC Trends Without Tier 2/Sulfur

Total VOC emissions produced nationwide by cars and trucks without Tier 2/Sulfur control are shown in Table III.A-5 and Figure III.A-7, broken down by relative contribution of evaporative emissions (across all cars and trucks), and exhaust emissions for LDVs, LDT1/2s and LDT3/4s. We project VOC emissions from light-duty vehicles will decline from approximately 2.8 million tons to 1.7 million tons between 2000 and 2015 as the fleet becomes increasingly dominated by cars and trucks complying with NLEV, Enhanced Evaporative control and SFTP requirements. Beginning in 2016, however, light-duty VOC emissions are projected to begin an upward trend due to VMT and vehicle fleet growth, increasing to 1.8 million tons by 2020 and 2.1 million tons by 2030. As shown in Figure III.A-7, our updated modeling projects much higher emissions, and an upturn in total light-duty VOC beginning in 2015.

Table III.A-5. 47-State Light-Duty VOC Emissions Without Tier 2/Sulfur (Annualized Summer Tons)

	Light-Duty	Contrib	ution by Emissio	n Source / Vehic	le Class	Light-Duty	
Year	Emissions: Air Quality	Evaporative					
	Analysis Modeling	(All LDV/LDT)	LDV	LDT1/2	LDT3/4	Updated Tier 2 Model	
2000	2,751,002	48%	23%	15%	14%	3,202,293	
2004	2,323,874	50%	19%	18%	13%	2,794,249	
2007	2,026,945	53%	16%	17%	13%	2,544,842	
2010	1,828,506	55%	14%	17%	14%	2,356,512	
2015	1,733,981	57%	11%	17%	16%	2,291,030	
2020	1,788,057	57%	10%	18%	16%	2,389,757	
2030	2,108,765	57%	9%	18%	15%	2,845,573	



Evaporative emissions are projected to be about 50 percent of the light-duty inventory in 2000, with this percent contribution rising steadily through 2030. Exhaust emissions from trucks also play an increasingly significant role in shaping the overall VOC trend. In 2000, we project that trucks will produce approximately 56 percent of exhaust VOC emissions; by 2015, trucks account for 75 percent of these emissions, while overall emissions produced by trucks increase steadily. The benefits from Tier 1, NLEV and SFTP are not as pronounced for trucks relative to cars, and are offset almost immediately by growth in truck VMT. As a result, exhaust VOC emissions from trucks see only modest initial reductions due to these programs before being offset by VMT growth.

Figures III.A-8 and III.A-9 show our projections of the contribution of light-duty vehicles and trucks to the total anthropogenic (i.e., human-caused) 2030 VOC inventory in the 47 states and in Atlanta (on an annualized summer basis) that were used in the air quality and economic benefits analysis. Table III.A-6 shows this same contribution across the 47 states and all four cities from 2007 through 2030. Nationally, cars and trucks produce 13 percent of total VOC emissions in 2007; this percentage declines in subsequent years before stabilizing at 11 percent by 2015. Relative to the national average, the light-duty contributions are lower in New York and Chicago and higher in Atlanta and Charlotte. For the latter two cities, we project that cars and trucks will contribute 17 and 15 percent of all VOC emissions in 2007.

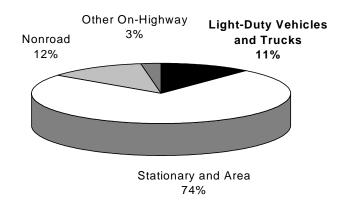


Figure III.A-8. Breakdown of Total 2030 47-State VOC Inventory Without Tier 2/Sulfur

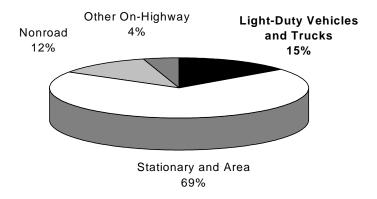


Figure III.A-9. Breakdown of Total 2030 Mthanta VOC Inventory Without Tier 2/Sulfur

Table III.A-6. Light-Duty Contribution to Total VOC Inventory Without Tier 2/Sulfur (Typical Ozone Season Day)

17	Air Quality Analysis Modeling							
Year	47 State	New York	Chicago	Atlanta	Charlotte	47 State		
2007	13%	6%	6%	17%	15%	15%		
2010	12%	-	-	-	-	14%		
2015	11%	-	-	-	-	14%		
2020	11%	-	-	-	-	14%		
2030	11%	6%	5%	15%	12%	15%		

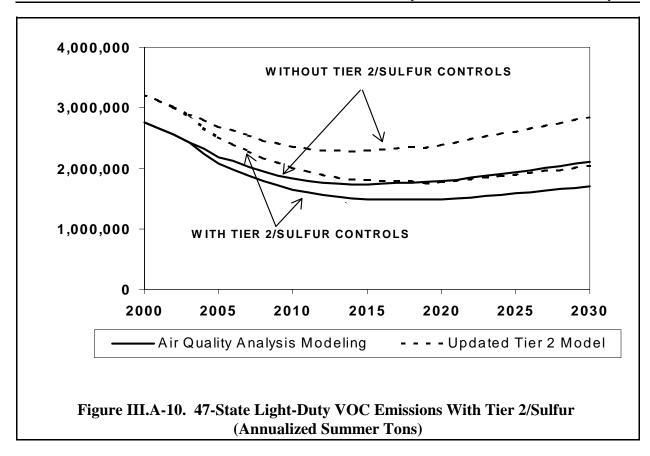
#### b. VOC Reductions Due To Tier 2/Sulfur

Table III.A-7 contains annual nationwide tons of VOC we project will be reduced due to today's action, encompassing the effects of low sulfur fuel and the introduction of Tier 2 light-duty vehicle and light-duty truck standards for both exhaust and evaporative emissions. Figure III.A-10 shows projected 47-state emissions with Tier 2/Sulfur control, broken down by light-duty evaporative emissions and exhaust emissions from LDVs, LDT1/2s and LDT3/4s.

Table III.A-7. 47-State Light-Duty VOC Reductions Due to Tier 2/Sulfur (Annualized Summer Tons)

	Air Qual	ity Analysis N	Modeling	Updated Tier 2 Model			
Year	Emissions	Percent Reduction in Baseline Inventory		Emissions	Percent Reduction in Baseline Inventory		
	Reduced	Light- Duty	All Sources*	Reduced	Light- Duty	All Sources*	
2004	85,688	4%	-	127,957	5%	-	
2007	143,507	7%	0.9%	262,174	10%	1.6%	
2010	178,886	10%	1.1%	349,126	15%	2.1%	
2015	244,080	14%	1.5%	491,336	21%	2.9%	
2020	305,470	17%	1.8%	615,239	26%	3.5%	
2030	400,968	19%	2.2%	806,343	28%	4.2%	

<sup>\*</sup> Includes emission reductions from Heavy-Duty Gasoline Vehicles due to sulfur control



Although not shown, emission reductions due to sulfur control could be realized as early as 2000 under the sulfur ABT program. In 2004, we project that the implementation of 120 ppm fuel will reduce light-duty emissions four percent, due almost entirely to reduced emission from Tier 0, Tier 1 and NLEV vehicles; this is the equivalent of emissions produced by seven million pre-Tier 2 cars and trucks. After 2004, further sulfur reductions and the introduction of LDT2s, LDT3s, and LDT4s complying with the Tier 2 NMOG standard and operating on low sulfur fuel reduce emission further. By 2030, the air quality analysis modeling projects that baseline light-duty VOC emissions are reduced 19 percent due to Tier 2/Sulfur control, the equivalent of emissions from 51 million pre-Tier 2 cars and trucks. This represents a 2.2 percent reduction of the total anthropogenic VOC inventory. Our more recent modeling suggests that reductions will in fact be significantly larger than the air quality analysis results; by 2030, light-duty VOC emissions are reduced nearly 30 percent, and total anthropogenic VOC emissions reduced 4.2 percent. Tier 2/Sulfur control is projected to delay the upturn in light-duty VOC emissions by five years.

It should be noted that both the air quality analysis modeling and updated Tier 2 Model assume a Tier 2 fleet average NMOG level of 0.09 grams/mile, which is the highest fleet average possible under the certification bin system. A more likely fleet average is in the range of 0.07 to

0.08 grams/mile; the actual VOC emission reductions realized from today's action will thus be even larger than presented here.

We project that heavy-duty gasoline vehicles would decrease emissions by approximately 4,500 tons per year in 2007 due to sulfur control; these reductions are included in the estimates of mobile source and all source percent reductions contained in Table III.A-7. In addition, reductions from "Medium Duty Passenger Vehicles" (e.g. passenger vehicles above 8500 pounds included as part of Tier 2 vehicle program) are estimated to be at least 9,500 tons in 2030.

Figures III.A-11 and III.A-12 show the contribution of light-duty cars and trucks to total 2030 VOC inventory in the 47 states and in Atlanta with Tier 2/Sulfur control. Table III.A-8 shows this same contribution across the 47 states in 2007, 2010, 2015 and 2030, and in the four cities in 2007 and 2030. By 2030, we project that the light-duty contribution will drop to 9 percent nationally, from 11 percent without Tier 2/Sulfur control. This trend will be similar across the four cities, depending on the level of light-duty contribution without Tier 2/Sulfur control. We project that with Tier 2/Sulfur control, car and truck emissions will contribute four percent of total emissions in New York and Chicago in 2030 (down from six and five percent, respectively), eight percent in Charlotte (down from 12 percent), and 11 percent in Atlanta (down from 15 percent).

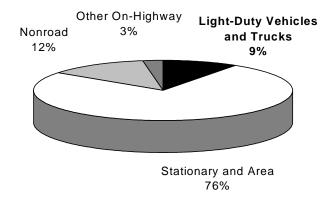


Figure III.A.-11. Breakdown of Total 2030 47-State VOC Inventory With Tier 2/Sulfur

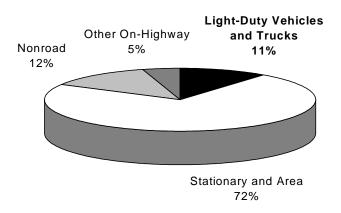


Figure III.A-12. Breakdown of Total 2030 Atlanta VOC Inventory With Tier 2/Sulfur

Table III.A-8. Light-Duty Contribution to Total VOC Inventory With Tier 2/Sulfur (Typical Ozone Season Day)

17		Air Quality Analysis Modeling							
Year	47 State	New York	Chicago	Atlanta	Charlotte	47 State			
2007	12%	6%	5%	15%	14%	14%			
2010	11%	-	-	-	-	13%			
2015	9%	-	-	-	-	11%			
2020	9%	-	-	-	-	11%			
2030	9%	4%	4%	11%	8%	11%			

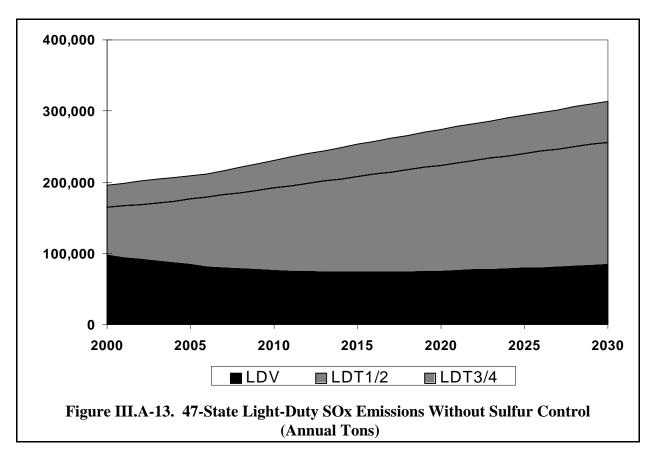
#### 3. SOx

### a. Light-Duty SOx Trends Without Sulfur Control

Gaseous SOx emissions are formed by the combustion of fuel sulfur, and hence depend entirely on the level of sulfur in the fuel. SOx emissions without sulfur control are shown in Table III.A-9 and Figure III.A-13, broken down by LDV, LDT1/2 and LDT3/4. As shown, we project that SOx emission levels will increase unabated through 2030 in conjunction with VMT growth in the absence of any action to reduce fuel sulfur levels. In 2000, we project light-duty vehicles and trucks will emit 196,000 tons of SOx; by 2030, this level is projected to be 314,000 tons, an increase of 60 percent. The absolute emission estimates presented in Table III.A.-9 are based on a 330 ppm average sulfur level for conventional gasoline; using our updated estimate for conventional gasoline of 300 ppm conventional gasoline, the values in this table would be reduced by approximately eight percent.

**Table III.A-9. 47-State SOx Emissions Without Sulfur Control (Annual Tons)** 

V	Emissions	Light-Duty	Light-Duty Contribution	Contribu	tion by Vehicle Class		
Year	From All Sources	Emissions	to All Sources	LDV	LDT1/2	LDT3/4	
2000	-	196,334	-	49%	34%	16%	
2004	-	206,258	-	42%	42%	16%	
2007	18,052,276	216,626	1.2%	37%	47%	16%	
2010	17,949,631	230,781	1.3%	33%	50%	17%	
2015	17,792,528	253,109	1.4%	29%	53%	18%	
2020	17,607,934	274,016	1.6%	27%	54%	18%	
2030	17,242,341	313,998	1.8%	27%	55%	18%	



Trucks, primarily LDT1s and LDT2s, are responsible for the steady increase in light-duty SOx emissions. While LDV SOx emissions are relatively stable, SOx emissions from trucks (and hence the contribution to light-duty inventory produced by trucks) are projected to increase steadily. In 2000, trucks account for roughly half of light-duty SOx emissions, growing to over 70 percent by 2015.

## b. SOx Reductions Due To Sulfur Control

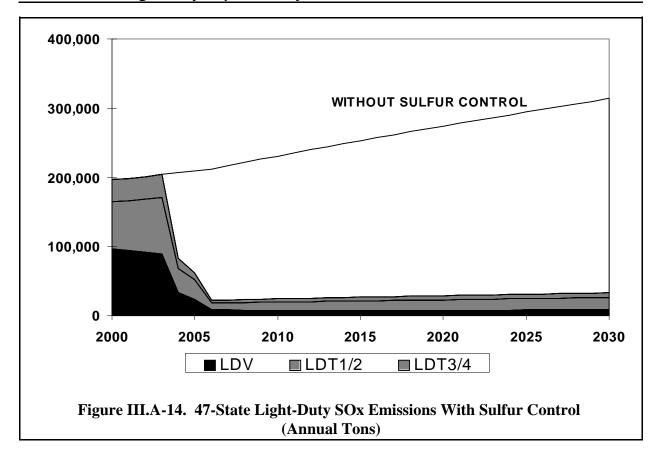
We project that today's proposal would immediately and substantially reduce SOx emissions from cars and trucks once its fuel sulfur provisions take effect. Table III.A-10 contains annual nationwide tons of gaseous SOx we project will be reduced from light-duty vehicles and trucks due to sulfur control. Figure III.A-14 shows SOx emissions after sulfur control, broken down by LDV, LDT1/2 and LDT3/4.

Table III.A-10. 47-State Light-Duty SOx Reductions Due To Sulfur Control (Annual Tons)

Year	Light-Duty Emissions	Light-Duty Emissions	Emissions		eduction in Inventory
Tear	Without Sulfur Control	With Sulfur Control	Reduced	Light-Duty	All Sources*
2004	206,258	82,408	123,850	60%	-
2007	216,626	22,847	193,779	89%	1.2%
2010	230,781	24,302	206,479	89%	1.4%
2015	253,109	26,652	226,457	89%	1.5%
2020	274,016	28,837	245,179	89%	1.6%
2030	313,998	32,982	281,016	89%	1.9%

<sup>\*</sup> Includes reductions from Heavy-Duty Gasoline Vehicles, Motorcycles and Nonroad Sources

Tier 2/Sulfur Regulatory Impact Analysis - December 1999



As shown, a significant reduction in light-duty SOx emissions would be realized immediately with sulfur control. The reductions presented above presume 120 ppm in 2004 and 90 ppm in 2005 under the sulfur ABT program; reductions could be realized as early as 2000 under this program. We project that nearly 90 percent of light-duty SOx emissions will be reduced when 30 ppm fuel is introduced in 2006. This relative reduction will remain constant beyond 2006 since SOx emissions are not reduced further as new Tier 2 VOC, NOx, and PM standards are phased in. The absolute level of emission reductions would become larger with time, however, due to VMT growth.

SOx emission reductions will also occur from heavy-duty gasoline vehicles and motorcycles due to sulfur control; we estimate this reduction to be approximately 10,000 tons in 2005, growing to 16,000 tons by 2030. In addition, emissions from all gasoline-powered nonroad equipment would be reduced due to sulfur control. We estimate this benefit would be approximately 25,000 tons per year on average between 2005 and 2020. These reductions, shown in Appendix A, are included in the percent reductions from all sources in Table III.A-10.

#### 4. Particulate Matter

Trends in particulate matter emissions will depend very strongly on the prevalence of diesel vehicles in the light-duty fleet. Currently, diesels make up a very small portion (less than one percent) of overall car and truck sales. However, sharp increases in diesel sales are a reasonable possibility given the focus on diesel technology for improving fuel economy under the Partnership for a New Generation of Vehicles (PNGV). Thus, we assessed PM emissions with and without Tier 2/Sulfur control under two sales scenarios: a "no growth" scenario, for which current diesel sales trends were assumed to continue, and an "increased growth" scenario, based on projections developed by A.D. Little, Inc. known as the "Most Likely" scenario. These projections estimate that diesels will grow to nine percent of light-duty vehicle sales and 24 percent of light-duty truck sales by 2015.<sup>7</sup> The inventory results presented in this section are for direct exhaust PM<sub>10</sub> emissions, comprising carbonaceous PM and sulfate emitted directly from the tailpipe and a subset of Total PM (which also includes direct non-exhaust PM from tire and brake wear, and indirect PM caused by secondary reactions to emitted NOx and SOx in the atmosphere). Direct PM<sub>2.5</sub> emissions are presented separately in Appendix A.

#### a. "No Growth" Diesel Sales Scenario

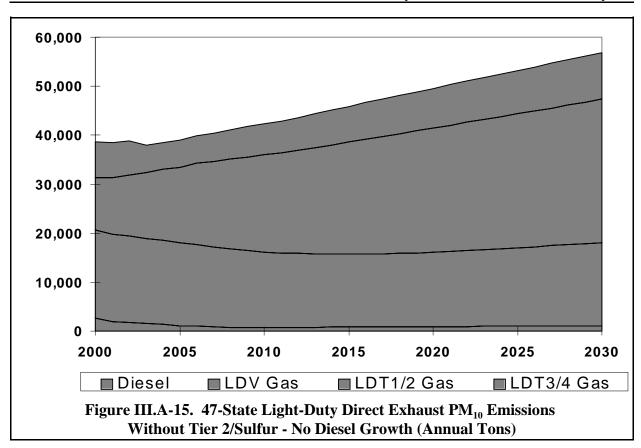
i. Light-Duty Direct Exhaust PM<sub>10</sub> Trends Without Tier 2/Sulfur

In general, gasoline vehicles emit PM at rates much lower than their diesel counterparts. Under the no growth scenario, direct PM emissions from the light-duty vehicle fleet are driven largely by sulfate emissions from gasoline vehicles, which depend primarily on gasoline fuel sulfur level. Without Tier 2/Sulfur control, these emissions increase at a steady rate in conjunction with VMT, as shown in Tables III.A-11 and Figure III.A-15. In 2000, we project that approximately 36,000 tons will be emitted annually by light-duty cars and trucks. This level is projected to exceed 48,000 tons in 2020 and reach nearly 56,000 tons in 2030. The absolute emission estimates presented in Table III.A.-11 are based on a 330 ppm average sulfur level for conventional gasoline; using our updated estimate for conventional gasoline of 300 ppm conventional gasoline, the values in this table would be reduced by approximately six percent.

Table III.A-11. 47 State Light-Duty Direct Exhaust PM<sub>10</sub> Emissions Without Tier 2/Sulfur No Growth in Diesel Sales (Annual Tons)

	Emissions	Light- Duty	Light-Duty Contribution	Contribution by Fuel Type / Vehicle Class			
Year	From All Sources*	Exhaust Emissions	to All Sources	Diesel LDV/LDT	Gas LDV	Gas LDT1/2	Gas LDT3/4
2000	-	38,729	-	7%	47%	28%	19%
2004	-	38,551	-	4%	45%	37%	14%
2007	2,907,819	40,365	1.4%	2%	40%	43%	14%
2010	2,945,927	42,385	1.4%	2%	36%	47%	15%
2015	3,058,635	45,887	1.5%	2%	32%	50%	16%
2020	3,168,482	49,577	1.6%	2%	31%	51%	16%
2030	3,431,450	56,861	1.7%	2%	30%	51%	17%

<sup>\*</sup> Excludes natural and miscellaneous sources (e.g., fugitive dust), but includes indirect sources such as tire and brake wear.



As expected, the diesel contribution to overall emissions in the no growth scenario is relatively small. Rather, gasoline trucks (primarily LDT1s and LDT2s) are responsible for the steady increase in PM emissions. Under this scenario, we project the contribution of gasoline trucks to light-duty PM<sub>10</sub> inventory to grow to 70 percent by 2030.

## ii. Direct Exhaust PM<sub>10</sub> Reductions Due To Tier 2/Sulfur Control

Under the no growth scenario, today's proposal would provide an immediate and substantive reduction in direct PM emissions from cars and trucks, due primary to sulfur control. Table III.A-12 contains annual nationwide tons of direct exhaust  $PM_{10}$  we project will be reduced from light-duty vehicles and trucks due to Tier 2/Sulfur control. Figure III.A-16 shows  $PM_{10}$  emissions after Tier 2/Sulfur control broken down by diesel (all light-duty cars and trucks) and gasoline LDV, LDT1/2 and LDT3/4.

Table III.A-12. 47-State Light-Duty Direct Exhaust PM<sub>10</sub> Reductions Due To Tier 2/Sulfur No Growth in Diesel Sales (Annual Tons)

Year	Light-Duty Emissions Without	Light-Duty Emissions With	Emissions		Percent Reduction in Baseline Inventory	
	Tier 2/Sulfur	Tier 2/Sulfur	Reduced	Light-Duty	All Sources*	
2004	38,551	24,424	14,127	37%	-	
2007	40,365	16,938	23,427	58%	0.8%	
2010	42,385	17,254	25,131	59%	0.9%	
2015	45,887	17,937	27,950	61%	0.9%	
2020	49,577	18,891	30,686	62%	1.0%	
2030	56,861	20,857	36,004	63%	1.1%	

<sup>\*</sup> Includes emission reductions from Heavy-Duty Gasoline Vehicles due to sulfur control. Excludes natural and miscellaneous sources (e.g., fugitive dust), but includes indirect sources such as tire and brake wear.

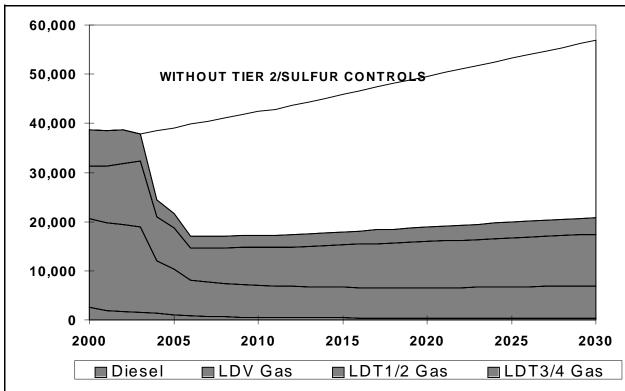


Figure III.A-16. 47-State Light-Duty Direct Exhaust PM<sub>10</sub> Emissions With Tier 2/Sulfur - No Diesel Growth (Annual Tons)

Reductions from gasoline vehicles would result almost entirely from sulfur control, rather than the proposed  $PM_{10}$  exhaust standards.  $PM_{10}$  emissions on current technology gasoline vehicles are much lower than diesel vehicles, and gasoline vehicle emissions are not expected to be reduced in response to the  $PM_{10}$  standards contained in today's proposal. As shown, a significant reduction in light-duty  $PM_{10}$  emissions would be realized immediately with sulfur control. The reductions presented above presume 120 ppm in 2004 and 90 ppm in 2005 under the sulfur ABT program; reductions could be realized as early as 2000 under this program. We project that nearly 60 percent of light-duty  $PM_{10}$  emissions will be reduced when 30 ppm fuel is introduced in 2006.

In addition to light-duty PM benefits, sulfur control would reduce  $PM_{10}$  emissions from heavy-duty gasoline vehicles. We estimate these benefits would be approximately 1,100 tons per year beginning with 30 ppm fuel, increasing to 1,500 tons by 2030. Across all sources, we project Tier 2/Sulfur control would reduce direct  $PM_{10}$  from all non-natural sources by about one percent.

#### b. "Increased Growth" Sales Scenario

Our "increased growth" scenario has been revised since the proposal. For the proposal, the increased growth scenario was developed with the intent of analyzing an upper bound for diesel growth, and assumed very aggressive levels of diesel penetration in the light truck market. Since the proposal, we have derived more realistic growth assumptions based on work by A.D Little, Inc.; the resulting growth scenario is referred to as the A.D. Little "Most Likely" diesel growth scenario. The original A.D. Little methodology presented sales penetrations for LDVs and LDTs in five-year increments, through 2015. We filled in the missing years using linear interpolation, and assumed no growth beyond 2015. For this analysis, we assumed that diesel LDT sales penetration would be distributed equally between the four truck classes. The resulting diesel sales penetrations are shown in Table III.A-13.

Table III.A-13. Diesel LDT Sales Penetration Under Increased Growth Scenario

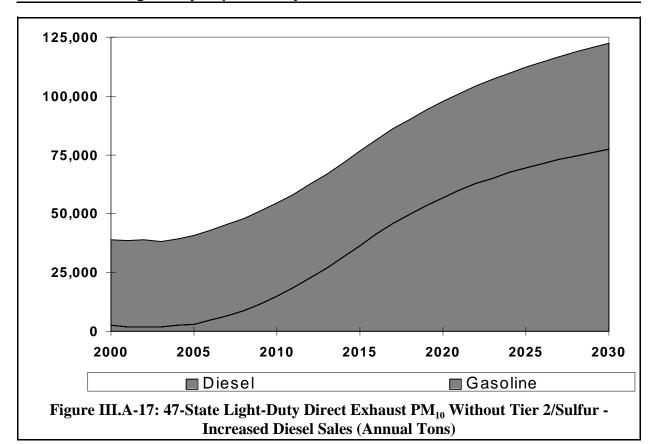
Model Year	Diesel Sales Penetration	
	LDV	LDT
2001	0.1%	0.1%
2002	0.1%	1.5%
2003	0.1%	3.0%
2004	0.1%	4.5%
2005	0.3%	6.0%
2006	0.7%	8.2%
2007	1.0%	10.4%
2008	1.3%	12.6%
2009	1.7%	14.8%
2010	2.0%	17.0%
2011	3.4%	18.4%
2012	4.8%	19.8%
2013	6.2%	21.2%
2014	7.6%	22.6%
2015 and later	9.0%	24.0%

# i. Light-Duty Direct Exhaust PM<sub>10</sub> Trends Without Tier 2/Sulfur

Our projections for light-duty direct exhaust  $PM_{10}$  under the increased diesel sales scenario are shown in Table III.A-14 and Figure III.A-17. As expected, this scenario is projected to result in dramatic increases in light-duty  $PM_{10}$  emissions. 2010 baseline emissions are approximately 54,000 tons, 28 percent higher than the 42,000 tons projected in the no growth diesel case from Table III.A-11. However, by 2030, we project this scenario would result in direct PM emissions of 123,000 tons, over two times higher than the emissions projected for the no growth scenario in the same year.

Table III.A-14. 47 State Light-Duty Direct Exhaust PM<sub>10</sub> Emissions Without Tier 2/Sulfur Increased Diesel Growth Scenario
(Annual Tons)

Year	Light-Duty Emissions Without Tier 2/Sulfur	Contribution	by Fuel Type
		Diesel LDV/LDT	Gasoline LDV/LDT
2000	38,729	7%	93%
2004	39,418	6%	94%
2007	44,749	13%	87%
2010	54,094	26%	74%
2015	76,309	47%	52%
2020	97,708	58%	42%
2030	122,608	63%	37%



As shown, the rapid growth of diesels in conjunction with high per-vehicle PM emissions from diesels drive overall direct PM emissions under this scenario. In 2007, we project diesels would already account for 13 percent of all light-duty emissions. Diesel contribution grows to over 25 percent by 2010 and over 60 percent by 2030.

## ii. Direct Exhaust PM<sub>10</sub> Reductions Due To Tier 2/Sulfur

Tier 2/Sulfur control would effectively neutralize excess PM emissions generated under our increased diesel penetration scenario. Table III.A-15 contains reductions in direct exhaust PM<sub>10</sub> emissions due to Tier 2/Sulfur standards for the increased diesel sales penetration case. Figure III.A-18 shows these emissions with Tier 2/Sulfur control, broken down by diesel and gasoline. It should be noted that these emission reductions assume an average PM certification standard of 0.01 grams per mile for all vehicles, and hence reflect a "best case" scenario for diesel growth. Under the certification bin system, it is likely that many diesels would certify in the 0.02 g/mi PM bin; under the "worst-case" scenario in which all diesels certify in this bin, we project that emissions in 2030 would be approximately 8,000 tons higher than the "With Tier"

2/Sulfur" scenario shown in Table III.A-15.9

Table III.A-15. 47-State Light-Duty Direct Exhaust PM<sub>10</sub> Reductions Due To Tier 2/Sulfur Increased Diesel Growth Scenario (Annual Tons)

Year	Light-Duty Emissions Without Light-Duty Emissions With Emissions With			Percent Reduction in Baseline Inventory		
	Tier 2/Sulfur	Tier 2/Sulfur	Reduced	Light-Duty	All Sources*	
2004	39,418	25,184	14,234	36%	-	
2007	44,749	19,017	25,732	58%	0.9%	
2010	54,094	19,502	34,592	64%	1.2%	
2015	76,309	20,511	55,798	73%	1.8%	
2020	97,708	21,928	75,780	78%	2.4%	
2030	122,608	24,838	97,770	80%	2.8%	

<sup>\*</sup> Includes emission reductions from Heavy-Duty Gasoline Vehicles due to sulfur control. Excludes natural and miscellaneous sources (e.g., fugitive dust), but includes indirect sources such as tire and brake wear.

In 2004, the fleet would still be comprised primarily of gasoline vehicles under this scenario; thus, significant benefits from gasoline sulfur control would be realized immediately, as with the no growth case. The rapid growth of diesel market penetration in conjunction with implementation of the proposed Tier 2 PM standards would result in a diesel fleet comprised almost exclusively of vehicles compliant with Tier 2. Thus, a large share of the baseline inventory would be reduced very soon after implementation of the Tier 2/Sulfur standards. By 2015, over 70 percent of baseline light-duty exhaust PM<sub>10</sub> inventory is reduced. By 2030, 80 percent of the baseline emissions would be reduced, nearly 3 percent of total inventory. As shown, today's action would largely serve to mitigate the PM<sub>10</sub> emission increases which would result from rapid diesel market penetration.

 $<sup>^9</sup>$  Under this "worst-case" PM scenario, all diesels under the A.D. Little "Most Likely" diesel sales case (Table III.A.-13) would certify in a bin with a 0.02 g/mi PM standard (0.2 or 0.15 g/mi NOx). The remaining vehicles (all gasoline) would certify in bins with a PM standard of 0.01 g/mi and a NOx standard or 0.07 g/mi or less.

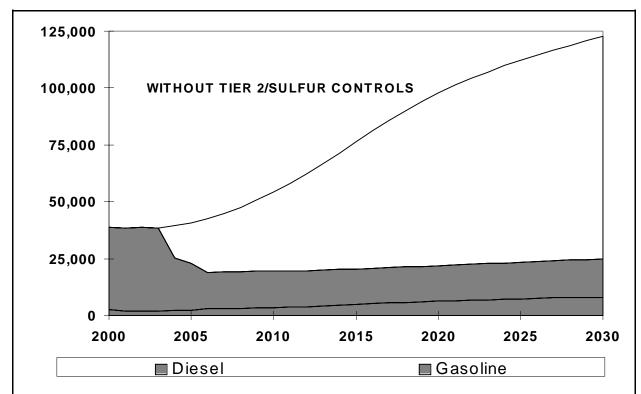


Figure III.A-16. 47-State Light-Duty Direct Exhaust  $PM_{10}$  Emissions With Tier 2/Sulfur - Increased Diesel Sales (Annual Tons)

#### B. Ozone: Baseline Nonattainment and Program Impacts

## 1. General Description of the EPA Ozone Modeling Used In This Rulemaking

A series of air quality modeling simulations were completed to a) support determination of the need for additional emissions reductions in order to meet the ozone NAAQS, b) assess the impact of the Tier 2/Sulfur rule on future ozone levels, and c) provide projected air quality information to support the benefits/cost analysis. The model simulations were performed for five emissions scenarios: a 1996 base year, a 2007 baseline projection, a 2007 projection with Tier 2/Sulfur controls, a 2030 baseline projection, and a 2030 projection with Tier 2/Sulfur controls. These scenarios and the underlying emissions inventories associated with each are described in Section III. A.

In conjunction with current air quality data, as explained below, the model output from the 2007 and 2030 baselines was used to identify areas expected to exceed the ozone NAAQS in 2007 and 2030. (These areas became candidates for being determined to be residual exceedance areas which will require additional emission reductions to attain and maintain the ozone NAAQS. As described in Section B.2, the impacts of the Tier 2/Sulfur controls were determined by comparing the model results in the future year control runs against the NLEV/high sulfur baseline simulations of the same year. The procedures for using the air quality modeling results in the benefits/costs analysis are described in Section IV. The remainder of this section provides a summary of the ozone modeling methodologies used to support this rulemaking. Additional details are provided in the Tier 2 Final Rule Air Quality Modeling Technical Support Document.

The structure of this section is as follows:

- Subsection 1.a. describes in general terms the ozone modeling that was used to determine the need for, and estimate the effects of, Tier 2/Sulfur controls.
- Subsection 1.b. describes the method used to determine residual non-attainment areas.

#### a. Modeling Methodology

A variable-grid version of the Urban Airshed Model (UAM-V) was utilized to estimate base and future-year ozone concentrations over the continental U.S. for the various emissions scenarios. UAM-V simulates the numerous physical and chemical processes involved in the formation, transport, and destruction of ozone. This model is commonly used for purposes of determining attainment/non-attainment as well as estimating the ozone reductions expected to occur from a reduction in emitted pollutants. The following sections provide an overview of the ozone modeling completed as part of this rulemaking. More detailed information is included in the Tier 2 Air Quality Modeling Technical Support Document (TSD).

## Modeling domains

Two separate modeling domains were utilized in the Tier 2/Sulfur analyses. The first covered that portion of the U.S. east of west longitude 99 degrees. The second covered the remainder of the U.S. west of west longitude 99 degrees. The model resolution was 36 km over the outer portions of each domain and 12 km in the inner portion of the grids. The model grids for the eastern U.S. modeling were portioned into nine vertical layers with a surface layer depth of 50 meters and a top level well above the typical mixed layer height (4000 meters). The model grids for the western U.S. modeling were portioned into eleven vertical layers with a surface layer depth of 50 meters and a top level of 4800 meters.

A recent modeling study (LADCO, 1999) considered the sensitivity of regional modeling strategies to grid resolution. This study showed that the spatial pattern and magnitude of the ozone changes at 4 km in response to emissions reductions were slightly more pronounced, but generally similar to the modeled changes at 12 km in the Lake Michigan area. The OTAG<sup>10</sup> modeling application also investigated the effects of grid resolution on national/regional control strategies (e.g., Tier 2/Sulfur). The OTAG Final Report concluded that: a) peak simulated ozone is generally higher with more highly resolved grids, b) spatial concentration patterns are comparable between the fine and the coarse grid, and c) NOx reductions produce widespread ozone decreases and occasional limited ozone increases with either the fine or the coarse grid (although the increases tend to be larger in magnitude when finer-scale grids are used). More detail on the effect of grid size upon model results is provided in the response to comments and the TSD for this rule.

#### Modeling episodes

Three multi-day meteorological scenarios during the summer of 1995 were used in the model simulations over the eastern U.S.: 12-24 June, 5-15 July, and 7-21 August. These periods featured ozone exceedances at various times over most areas of the eastern U.S.<sup>11</sup>. In general, these episodes do not represent extreme ozone events but, instead, are generally representative of ozone levels near local design values<sup>12</sup>. Five simulations were completed for the June and July

<sup>&</sup>lt;sup>10</sup> The OTAG modeling project is used as a benchmark for the Tier 2/Sulfur modeling because it is the most extensive regional ozone modeling application completed to date in terms of days modeled, areas covered, and efforts of the air pollution modeling community to obtain sound model performance.

<sup>&</sup>lt;sup>11</sup> Each modeling episode contains three days for which the modeling results are not considered. These days are simulated to minimize the dependence of the modeling results on uncertain initial conditions.

<sup>&</sup>lt;sup>12</sup> The fourth highest daily maximum 1-hour average ozone concentration measured over a three-year period at a given monitor is the design value. Design values are used to determine the attainment status of a given region.

episodes (1996 base, 2007 baseline, 2007 control, 2030 baseline, 2030 control). Three simulations were completed for the August episode (1996 base, 2007 baseline, 2007 control).

Two episodes were modeled for the western U.S. domain: 5-15 July 1996 and 18-31 July 1996. Again, these 19 days contained design value level ozone exceedances over most of the western U.S. allowing for an assessment of emission controls in polluted, but not infrequent, conditions. The primary purpose of simulating the western episodes was to provide data for the benefits/cost analysis for 2030. Thus, no 2007 simulations were made for the West.

#### Non-emissions modeling inputs

The meteorological data required for input into UAM-V (wind, temperature, vertical mixing, etc.) were developed by a separate meteorological model, the Regional Atmospheric Modeling System (RAMS) for the eastern U.S. 1995 episodes, and the Fifth-Generation National Center for Atmospheric Research (NCAR) / Penn State University (PSU) Mesoscale Model (MM5) for the western U.S. 1996 episodes. These models provided needed data at every grid cell on an hourly basis. These meteorological modeling results were evaluated against observed weather conditions before being input into UAM-V and it was concluded that the model fields were adequate representations of the historical meteorology.

The modeling assumed background pollutant levels at the top and along the periphery of the domain. Additionally, initial conditions were assumed to be relatively clean as well. Given the ramp-up days and the expansive domains, it is expected that these assumptions will not affect the modeling results, except in areas near the boundary (e.g., Dallas-Fort Worth TX). The other non-emission UAM-V inputs (land use, photolysis rates, etc.) were developed using procedures employed in the OTAG regional modeling. The development of model inputs is discussed in greater detail in the Tier 2 Air Quality Technical Support Document.

#### Model performance evaluation

The purpose of the Tier 2/Sulfur base year modeling was to reproduce the atmospheric processes resulting in the observed ozone concentrations over these domains and episodes. One of the fundamental assumptions in ozone modeling is that a model which closely replicates observed ozone in the base year can be used to support future-year policymaking.

As with previous regional photochemical modeling studies, the accuracy of the Tier 2/Sulfur model base year simulations of historical ozone patterns varies by day and by location over this large modeling domain. From a qualitative standpoint, there appears to be considerable similarity on most days between the observed and simulated ozone patterns. Additionally, where possible to discern, the model appears to follow the regional-scale ozone trends fairly closely.

The values of two primary measures of model performance, mean normalized bias and

mean normalized gross error, indicate that the Tier 2/Sulfur modeling over the eastern U.S. is generally as good or better than the grid modeling done for OTAG<sup>13</sup>, as shown in Table III.B-1. As OTAG did not perform any modeling for the West, no comparison back to OTAG is possible for the Tier 2 western U.S. model performance. Mean normalized bias is defined as the average difference between model predictions and observations (paired in space and time) normalized by the observations. Mean gross error is defined as the average absolute difference between model predictions and observations, paired in space and time, normalized by the observations. EPA guidance on local ozone attainment demonstration modeling (not the purpose of the Tier 2 modeling) suggests biases be less than 5-15 percent and error be less than 30-35 percent.

Table III.B-1. Comparison of eastern U.S. regional model performance statistics between the Ozone Transport Assessment Group (OTAG) modeling used to support the  $NO_{\rm X}$  SIP call and the Tier 2/Sulfur modeling. The units are percentages.

Mean Normalized Bias	OTAG 1988 Episode	OTAG 1991 Episode	OTAG 1993 Episode	OTAG 1995 Episode	Tier 2 June 95 Episode	Tier 2 July 95 Episode	Tier 2 August 95 Episode
Domain	-8	-4	+1	+4	-10	-6 (-4) <sup>14</sup>	+2
Midwest	-15	-8	-8	-5	-11	-13 (-8)	+7
Northeast	-3	-6	-8	+8	-17	-9 (-9)	-9
Southeast	+2	+15	+21	+9	-4	+4 (+5)	+7
Southwest	-6	+6	+2	+12	+2	+8 (+8)	+6

Mean Normalized Gross Error	OTAG 1988 Episode	OTAG 1991 Episode	OTAG 1993 Episode	OTAG 1995 Episode	Tier 2 June 95 Episode	Tier 2 July 95 Episode	Tier 2 August 95 Episode
Domain	28	25	27	25	24	24 (24)	23
Midwest	27	26	25	24	24	26 (25)	22
Northeast	29	23	23	26	27	22 (21)	24
Southeast	28	25	32	27	20	24 (24)	22
Southwest	22	24	23	29	24	27 (26)	24

In general, the model underestimates ozone for the June and July eastern episodes in 1995

<sup>&</sup>lt;sup>13</sup> Again, the OTAG application is used as a relative benchmark for model performance because it is the most detailed modeling to date over this region.

<sup>&</sup>lt;sup>14</sup> Values in parentheses are for the 10-15<sup>th</sup> only. These dates correspond with OTAG episode days.

and, especially, both western episodes in 1996. The under prediction bias in the western U.S. modeling averages about 40 percent. The model is slightly biased toward overestimation in the August 1995 eastern episode. Although the overall tendency is to underestimate the observed ozone, there are several instances in which overestimations occurred. The net effect is expected to be an underestimate of the total extent of future-year exceedances, although some individual areas may be overstated.

#### Application of the modeling results

As discussed in the preamble and in other sections of this document, the grid modeling is being utilized to support the need for the Tier 2/Sulfur rulemaking and to determine the effects of the emissions reductions on ozone air quality, with results reported at the level of CMSAs and MSAs, as described in Section III.B.3, below. Section VII of this document discusses how these modeling results are used in the cost benefit analysis.

#### b. Determining Need for Additional Emissions Reductions

Table III.B-1 of the Tier 2/Sulfur preamble lists those metropolitan areas which were determined to require additional emission reductions in order to attain and maintain the 1-hour ozone NAAQS. This determination was made for all areas with current design values greater than or equal to 125 ppb and with modeling evidence that exceedances will persist into the future<sup>15</sup>. The following sections provide the details inherent in both parts of this determination.

#### Air quality design values

An ozone design value is the concentration that determines whether a monitoring site meets the NAAQS for ozone. Because of the way they are defined, design values are determined based on three consecutive-year monitoring periods. A 1-hour design value is the fourth highest daily maximum 1-hour average ozone concentration measured over a three-year period at a given monitor. The full details of these determinations (including accounting for missing values and other complexities) are given in Appendices H and I of 40 CFR Part 50. As discussed in these appendices, design values are truncated to whole part per billion (ppb). Due to the precision with which the standards are expressed (0.12 parts per million (ppm) for the 1-hour, a violation of the 1-hour standard is defined as a design value greater than or equal to 125 ppb.

For a county, the design value is the highest design value from among all the monitors with valid design values within that county. If a county does not contain an ozone monitor, it does not have a design value. For most of our analyses, county design values are consolidated where possible into design values for consolidated metropolitan statistical areas (CMSA) or

<sup>&</sup>lt;sup>15</sup> Modeling evidence from non-EPA analyses were also considered, as described in Section III.B.3, below.

metropolitan statistical areas (MSA). The design value for a metropolitan area is the highest design value among the included counties. Counties that are not in metropolitan areas are treated separately. For the purposes of defining the current design value of a given area, the higher of the 1995-1997 and 1996-1998 design values were chosen to provide greater confidence in identifying areas likely to have an ozone problem in the future. The 1995-1997 and 1996-1998 design values are listed in the Tier 2 Air Quality Modeling Technical Support Document.

#### *Method for projecting future exceedances*

The exceedance method was used for interpreting the future-year modeling results to determine where nonattainment is expected to occur in the 2007 and 2030 Base Cases<sup>16</sup>. As part of this method the modeling grid cells are first assigned to individual areas. The daily maximum 1-hour ozone values predicted in grid cells assigned to an area are then checked to identify whether there are any predictions >=125 ppb. Areas with current measured violations of the one-hour ozone standard, one or more model-predicted exceedances, and no conflicting modeling evidence to the contrary are projected to have a nonattainment problem in the future. This procedure is further described in the Tier 2 Air Quality Modeling Technical Support Document.

## 2. Ozone Reductions Expected from this Rule

The large reductions in emissions of ozone precursors from today's standards will be very beneficial to federal and State efforts to lower ozone levels and bring about attainment with the current one-hour ozone standards. The air quality modeling for the final rule shows that improvements in ozone levels are expected to occur throughout the country because of the Tier 2/Gasoline Sulfur program.<sup>17</sup> EPA found that the program significantly lowers model-predicted exceedances of the ozone standard. In 2007 the number of exceedances in CMSA/MSAs is forecasted to decline by nearly one-tenth and in 2030, when full turnover of the vehicle fleet has occurred, the program lowers such exceedances by almost one-third. In these same areas, the total amount of ozone above the NAAQS is forecasted to decline by about 15 percent in 2007 and by more than one-third in 2030. In the vast majority of areas, the air quality modeling predicts that the program will lower peak summer ozone concentrations for both 2007 and 2030. The reduction in daily maximum ozone is nearly 2 ppb, on average in 2007 and over 5 ppb, on average in 2030. These reductions contribute to EPA's assessment that the program will provide the large set of public health and environmental benefits summarized in Section VII. The forecasted impacts of the program on ozone in 2007 and 2030 are further described in the Tier 2 Air Quality Modeling Technical Support Document.

<sup>&</sup>lt;sup>16</sup> 2030 is the relevant baseline scenario for the western U.S. domain

<sup>&</sup>lt;sup>17</sup>EPA assessment of air quality changes for 2007 and 2030 focused on 37 States in the East because these States cover most of the areas with 1-hour nonattainment problems.

During the public comment period on the proposed rule, EPA received several comments that expressed concern about potential increases in ozone that might occur as a result of this rule. As indicated above, the air quality modeling results indicate an overall reduction in ozone levels in 2007 and 2030 during the various episodes modeled. In addition to ozone reductions, a few areas had predicted ozone increases in portions of the area during parts of the episodes modeled. In most of these cases, the overall decrease led EPA to conclude that there will be a net reduction in ozone levels in these areas due to the Tier 2/Sulfur program. In the very small number of exceptions to this, the Agency did find benefit from reduction of peak ozone levels. Based upon a careful examination of this issue, including EPA's modeling results as well consideration of the modeling and analyses submitted by commenters, it is clear that the significant ozone reductions from this rule outweigh the limited ozone increases that may occur. Additional details on this issue are provided in the Response to Comments Document and in the Tier 2 Air Quality Modeling Technical Support Document.

Collectively, EPA believes these results indicate that it will be much easier for States to provide EPA assurances that their State Implementation Plans will attain and maintain compliance with the one-hour ozone standards. In the limited number of cases mentioned above, EPA will work with States who will be conducting more detailed local modeling of their specific local programs that they have designed to provide attainment. Notably, there are also other upcoming federal measures to lower ozone precursors will aid these efforts. If the State modeling of local programs shows a need, the Agency will work with states to plan further actions to produce attainment with the NAAQS in order to protect the public's health and the environment. Further details on EPA's modeling results can be found in the response to comments and technical support documents.

# 3. Ozone Modeling and Analysis in 1-Hour State Implementation Plan Submittals and Other Local Ozone Modeling

#### a. Overview

We have reviewed and recently proposed action on SIP submissions from 14 states covering 10 serious and severe 1-hour ozone nonattainment areas. We received these submissions as part of the three-phase SIP process allowed by EPA guidance memos or as part of a request for an attainment date extension. These submissions also provided ozone modeling results for two attainment areas in a downwind state. These submissions contain local ozone modeling which we considered along with the results of the EPA ozone modeling described above. We have also considered ozone modeling submitted as part of an attainment date extension request for Beaumont-Port Arthur, TX, but have not yet taken action on that request. We have also reviewed a status report on the results of modeling being conducted in anticipation of submittal to EPA as part of an extension request for Dallas, TX. Finally, we have considered information in the most recent SIP submittal from California for the South Coast Air Basin. Table III.B-2 lists the areas involved, our overall conclusion as to whether the modeling

demonstrates attainment without reductions that would be considered "further reductions" under CAA section 202(i), and whether the area is included in our recent proposals for actions on SIP submittals. The Federal Register notices for these recent proposals appeared together on December 16, 1999, beginning at 64 FR 70318. This section discusses the background for the submissions and our conclusions from them.

The local modeling analyses generally cover a modeling domain encompassing one or a few closely spaced nonattainment areas and a limited upwind area. Because of this limited domain, states have been able to use grid cells of 4 or 5 kilometers on a side, in keeping with EPA guidance for such modeling. This fine grid size is an important factor in how much weight we have given to this set of evidence. The future attainment date examined differs from state to state depending on its current (or proposed extended) attainment deadline. In the state modeling, ozone episode days were selected by the respective states based on days with high ozone in the local domain being modeled. In all cases, the selection of episode days met our guidance. The local modeling also makes use of more information on the local emission inventory and control program than is practicable to include in broad scale modeling by EPA as described above.

The SIP submissions for these 10 nonattainment areas contain many legally required elements in addition to the attainment demonstrations. After considering the attainment demonstrations and these other elements, we have proposed appropriate action on each of these submissions. In many cases, we have proposed alternative actions on our part, based on whether the state submits additional SIP elements which we have described as necessary. We also explained what each state m

ust provide us in order to allow us to take final approval or conditional approval action.

More specific descriptions of the ozone modeling contained in the SIPs, for areas where we have recently proposed action on a submittal, and more explanation of our evaluation of it can be obtained in the individual Federal Register notices and in the technical support document prepared for each action.

Table III.B-2. Nonattainment Areas For Which EPA Has Recently Proposed Action On SIP Submissions Containing 1-hour Ozone Attainment Demonstrations or Otherwise Has Considered Results of Local Ozone Modeling

Nonattainment Area (Major Metro Area)	Affected States	Attainment Date	Demonstrates Attainment Without "Further Reductions"	Proposed for Action in December 16, 1999 Federal Register (64 FR 70318)
Western Massachusetts (Springfield)	MA	2003 (Requested Extension)	Yes	Yes
Greater Connecticut (Hartford and other MSAs)	СТ	2007 (Requested Extension)	Yes	Yes
New York City	NY, CT, NJ	2007	No	Yes
Philadelphia	PA, NJ, DE, MD	2005	No	Yes
Baltimore	MD	2005	No	Yes
Washington, D.C.	MD, VA, D.C.	2005 (Requested Extension)	No	Yes
Atlanta	GA	2003 (Requested Extension)	No	Yes
Houston	TX	2007	No	Yes
Chicago	IL, IN	2007	Yes	Yes
Milwaukee	WI	2007	Yes	Yes
Benton Harbor	MI	Not Applicable	Yes	No
Grand Rapids	MI	Not Applicable	Yes	No
Dallas	TX	2007	No	No

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Nonattainment Area (Major Metro Area)	Affected States	Attainment Date	Demonstrates Attainment Without "Further Reductions"	Proposed for Action in December 16, 1999 Federal Register (64 FR 70318)
Beaumont-Port Arthur	TX	2007 (Requested Extension)	No	Yes
South Coast Air Basin	CA	2010	No	No

## b. CAA Requirements and EPA Policy

The CAA, as amended in 1990, required EPA to designate as nonattainment any area that was violating the 1-hour ozone standard, generally based on air quality monitoring data from the three-year period from 1987-1989. CAA § 107(d)(4); 56 FR 56694 (Nov. 6, 1991). The CAA further classified these areas, based on the area's design value, as marginal, moderate, serious, severe or extreme. Marginal areas were suffering the least significant air pollution problems while the areas classified as severe and extreme had the most significant air pollution problems.

The control requirements and dates by which attainment needs to be achieved vary with the area's classification. Marginal areas are subject to the fewest mandated control requirements and have the earliest attainment date. Severe and extreme areas are subject to more stringent planning requirements but are provided more time to attain the standard. Serious areas were required to attain the 1-hour standard by November 15, 1999 and severe areas are required to attain by November 15, 2005 or November 15, 2007.

Under section 182(c)(2) and (d) of the CAA, serious and severe areas were required to submit demonstrations of how they would attain the 1-hour standard and how they would achieve reductions in VOCs and NOx emissions of 9 percent for each three-year period until the attainment year (rate-of-progress or ROP) by November 15, 1994.

In general, an attainment demonstration SIP includes a modeling analysis component showing how the area will achieve the standard by its attainment date and the control measures necessary to achieve those reductions. Another component of the attainment demonstration SIP is a motor vehicle emissions budget for transportation conformity purposes. Transportation conformity is a process for ensuring that States consider the effects of emissions associated with new or improved federally-funded roadways on attainment of the standard. As described in section 176(c)(2)(A), attainment demonstrations necessarily include the estimates of motor vehicle emissions that are consistent with attainment, which then act as a budget or ceiling for the purposes of determining whether transportation plans and projects conform to the attainment SIP.

Notwithstanding significant efforts by the States, in 1995 EPA recognized that many States in the eastern half of the United States could not meet the November 1994 time frame for submitting an attainment demonstration SIP because emissions of NOx and VOCs in upwind States (and the ozone formed by these emissions) affected these nonattainment areas and the full impact of this effect had not yet been determined. This phenomenon is called ozone transport.

On March 2, 1995, Mary D. Nichols, EPA's then Assistant Administrator for Air and Radiation, issued a memorandum to EPA's Regional Administrators acknowledging the efforts made by States but noting the remaining difficulties in making attainment demonstration SIP

submittals.<sup>8</sup> Recognizing the problems created by ozone transport, the March 2, 1995 memorandum called for a collaborative process among the States in the eastern half of the country to evaluate and address transport of ozone and its precursors. This memorandum led to the formation of the Ozone Transport Assessment Group (OTAG)<sup>9</sup> and provided for the States to submit the attainment demonstration SIPs based on the expected time frames for OTAG to complete its evaluation of ozone transport.

In June 1997, OTAG concluded and provided EPA with recommendations regarding ozone transport. The OTAG generally concluded that transport of ozone and the precursor NOx is significant and should be reduced regionally to enable States in the eastern half of the country to attain the ozone NAAQS.

In recognition of the length of the OTAG process, in a December 29, 1997 memorandum, Richard Wilson, EPA's then Acting Assistant Administrator for Air and Radiation, provided until April 1998 for States to submit for attainment demonstration SIPs and clarified that, by April 1998, States with serious and higher classified nonattainment areas additionally needed to submit (1) evidence that the applicable control measures in subpart 2 of part D of title I of the CAA were adopted and implemented or were on an expeditious course to being adopted and implemented; (2) a list of measures needed to meet the remaining ROP emissions reduction requirement and to reach attainment; (3) for severe areas only, a commitment to adopt the control measures necessary for attainment and ROP plans through the attainment year by the end of 2000; (4) a commitment to implement the SIP control programs in a timely manner and to meet ROP emissions reductions and attainment; and (5) evidence of a public hearing on the State submittal.<sup>10</sup>

Building upon the OTAG recommendations and technical analyses, in November 1997, EPA proposed action addressing the ozone transport problem. In its proposal, the EPA found that current SIPs in 22 States and the District of Columbia (23 jurisdictions) were insufficient to provide for attainment and maintenance of the 1-hour standard because they did not regulate NOx emissions that significantly contribute to ozone transport. 62 FR 60318 (Nov. 7, 1997). The EPA finalized that rule in September 1998, calling on the 23 jurisdictions to revise their SIPs to require NOx emissions reductions within the State to a level consistent with a NOx emissions budget identified in the final rule. 63 FR 57356 (Oct. 27, 1998). This final rule is commonly referred to as the NOx SIP Call or the Regional Ozone Transport Rule.

On July 16, 1998, EPA's then Acting Assistant Administrator, Richard Wilson, issued a guidance memorandum intended to provide further relief to areas affected by ozone transport. The memorandum recognized that many moderate and serious areas are affected by transported pollution from either an upwind area in the same State with a higher classification and later attainment date, and/or from an upwind area in another State that is significantly contributing to the downwind area's nonattainment problem. The policy recognized that some downwind areas may be unable to meet their own attainment dates, despite doing all that was required in their

local area, because an upwind area may not have adopted and implemented all of the controls that would benefit the downwind area through control of transported ozone before the downwind area's attainment date. Thus, the policy provided that upon a successful demonstration that an upwind area has interfered with attainment and that the downwind area is adopting all measures required for its local area for attainment but for this interference, EPA may grant an extension of the downwind area's attainment date. Local area measures would include all of the measures within the modeling domain that were relied on for purposes of the modeled attainment demonstration. Once an area receives an extension of its attainment date based on transport, the area would no longer be subject to reclassification to a higher classification and subject to additional requirements for failure to attain by its original attainment date provided it was doing all that was necessary locally. The policy provides that the area must meet four criteria to receive an attainment date extension. In summary, the area must: (1) be identified as a downwind area affected by transport from either an upwind area in the same State with a later attainment date or an upwind area in another State that significantly contributes to downwind nonattainment; (2) submit an approvable attainment demonstration with any necessary, adopted local measures and with an attainment date that reflects when the upwind reductions will occur; (3) adopt all local measures required under the area's current classification and any additional measures necessary to demonstrate attainment; and (4) provide that it will implement all adopted measures as expeditiously as practicable, but no later than the date by which the upwind reductions needed for attainment will be achieved.

The States generally submitted the SIPs between April and October of 1998; some States are still submitting additional revisions. Under the CAA, EPA is required to approve or disapprove a State's submission no later than 18 months following submission. (The statute provides up to 6 months for a completeness determination and an additional 12 months for approval or disapproval.)

#### c. Local Ozone Modeling in SIP Submissions

The EPA provides that States may rely on a modeled attainment demonstration supplemented with additional evidence to demonstrate attainment. In order to have a complete modeling demonstration submission, States have submitted the required modeling analysis and identified any additional evidence that EPA should consider in evaluating whether the area will attain the standard.

For purposes of demonstrating attainment, the CAA requires serious and severe areas to use photochemical grid modeling or an analytical method EPA determines to be as effective. The EPA has issued guidance on the air quality modeling that is used to demonstrate attainment with the 1-hour ozone NAAQS.<sup>12</sup> The photochemical grid model is set up using meteorological conditions conducive to the formation of ozone. Emissions for a base year are used to evaluate the model's ability to reproduce actual monitored air quality values and to predict air quality changes in the attainment year due to the emission changes which include growth up to and

controls implemented by the attainment year. A modeling domain is chosen that encompasses the nonattainment area. Attainment is demonstrated when all predicted concentrations inside the modeling domain are at or below the NAAQS or at an acceptable upper limit above the NAAQS permitted under certain conditions by EPA's guidance. When the predicted concentrations are above the NAAQS, an optional weight of evidence determination which incorporates but not is limited to other analyses such as air quality and emissions trends may be used to address uncertainty inherent in the application of photochemical grid models.

The EPA guidance identifies the features of a modeling analysis that are essential to obtain credible results. First, the State must develop and implement a modeling protocol. The modeling protocol describes the methods and procedures to be used in conducting the modeling analyses and provides for policy oversight and technical review by individuals responsible for developing or assessing the attainment demonstration (State and local agencies, EPA Regional offices, the regulated community, and public interest groups). Second, for purposes of developing the information to put into the model, the State must select air pollution days, i.e., days in the past with bad air quality, that are representative of the ozone pollution problem for the nonattainment area. Third, the State needs to identify the appropriate dimensions of the area to be modeled, i.e., the domain size. The domain should be larger than the designated nonattainment area to reduce uncertainty in the boundary conditions and should include large upwind sources just outside the nonattainment area. In general, the domain is considered the local area where control measures are most beneficial to bring the area into attainment. Fourth, the State needs to determine the grid resolution. The horizontal and vertical resolutions in the model affect the dispersion and transport of emission plumes. Artificially large grid cells (too few vertical layers and horizontal grids) may dilute concentrations and may not properly consider impacts of complex terrain, complex meteorology, and land/water interfaces. Fifth, the State needs to generate meteorological that describe atmospheric conditions and emissions inputs. Finally, the State needs to verify the model is properly simulating the chemistry and atmospheric conditions through diagnostic analyses and model performance tests. Once these steps are satisfactorily completed, the model is ready to be used to generate air quality estimates to support an attainment demonstration.

The modeled attainment test compares model predicted 1-hour daily maximum concentrations in all grid cells for the attainment year to the level of the NAAQS. A predicted concentration above 0.124 ppm ozone indicates that the area is expected to exceed the standard in the attainment year and a prediction below 0.124 ppm indicates that the area is expected to attain the standard. This type of test is often referred to as an exceedance test. The EPA's guidance recommends that States use either of two modeled attainment or exceedance tests for the 1-hour ozone NAAQS: a deterministic test or a statistical test.

The deterministic test requires the State to compare predicted 1-hour daily maximum

ozone concentrations for each modeled day<sup>18</sup> to the attainment level of 0.124 ppm. If none of the predictions exceed 0.124 ppm, the test is passed.

The statistical test takes into account the fact that the form of the 1-hour ozone standard allows exceedances. If, over a three-year period, the area has an average of one or fewer exceedances per year, the area is not violating the standard. Thus, if the State models a very extreme day, the statistical test provides that a prediction above 0.124 ppm up to a certain upper limit may be consistent with attainment of the standard. (The form of the 1-hour standard allows for up to three readings above the standard over a three-year period before an area is considered to be in violation.)

The acceptable upper limit above 0.124 ppm is determined by examining the size of exceedances at monitoring sites which *meet or attain* the 1-hour NAAQS. For example, a monitoring site for which the four highest 1-hour average concentrations over a three-year period are 0.136 ppm, 0.130 ppm, 0.128 ppm and 0.122 ppm is attaining the standard. To identify an acceptable upper limit, the statistical likelihood of observing ozone air quality exceedances of the standard of various concentrations is equated to severity of the modeled day. The upper limit generally represents the maximum ozone concentration level observed at a location on a single day and it would be the only level above the standard that would be expected to occur no more than an average of once a year over a three-year period. Therefore, if the maximum ozone concentration predicted by the model is below the acceptable upper limit, in this case 0.136 ppm, then EPA might conclude that the modeled attainment test is passed. Generally, exceedances well above 0.124 ppm are very unusual at monitoring sites meeting the NAAQS. Thus, these upper limits are rarely significantly higher than the attainment level of 0.124 ppm.

When the modeling does not conclusively demonstrate that the area will attain, additional analyses may be presented to help determine whether the area will attain the standard. As with other predictive tools, there are inherent uncertainties associated with modeling and its results. For example, there are uncertainties in some of the modeling inputs, such as the meteorological and emissions data bases for individual days and in the methodology used to assess the severity of an exceedance at individual sites. The EPA's guidance recognizes these limitations, and provides a means for considering other evidence to help assess whether attainment of the NAAQS is likely. The process by which this is done is called a weight of evidence (WOE) determination.

Under a WOE determination, the State can rely on and EPA will consider factors such as other modeled attainment tests, e.g., a rollback analysis; other modeled outputs, e.g., changes in the predicted frequency and pervasiveness of exceedances and predicted changes in the design value; actual observed air quality trends; estimated emissions trends; analyses of air quality

<sup>&</sup>lt;sup>18</sup>The initial, "ramp-up" days for each episode are excluded from this determination.

monitored data; the responsiveness of the model predictions to further controls; and, whether there are additional control measures that are or will be approved into the SIP but were not included in the modeling analysis. This list is not an exclusive list of factors that may be considered and these factors could vary from case to case. The EPA's guidance contains no limit on how close a modeled attainment test must be to passing to conclude that other evidence besides an attainment test is sufficiently compelling to suggest attainment. However, the further a modeled attainment test is from being passed, the more compelling the WOE needs to be.

Special explanation is necessary on the issue of how the NOx SIP Call/Regional Ozone Transport Rule has been handled by states in their local ozone modeling. For purposes of CAA section 202(i) we consider the emission reductions that will be achieved by the NOx SIP Call/Regional Ozone Transport Rule to be previous emission reductions rather than "further" reductions, since the 22 affected states and the District of Columbia are currently under an enforceable requirement to obtain these reductions. In most of the local ozone modeling in these SIP revisions, upwind NOx reductions have been assumed to occur through implementation of the NOx SIP Call/Regional Ozone Transport Rule in some or all of the states subject to that rule, even though all states' rules to implement those reductions have not yet been adopted. Where upwind and local implementation of the NOx SIP Call is assumed, our conclusion that the modeling shows that an area cannot attain the NAAQS means that it cannot attain even with the prior implementation of the NOx SIP Call, and thus the area requires further emission reductions under section 202(i).<sup>19</sup>

#### d. Conclusions from the Local Modeling in SIP Submittals

All of the states have made use of the weight of evidence concept in their attainment demonstrations. EPA has proposed to find that some of the demonstrations are adequate, while for others additional reductions are needed to attain. There is an important distinction between our proposed finding on these SIPs and the determination required by CAA section 202(i). We are in some cases proposing to approve demonstrations that depend on emission reductions from measures that the state has not yet adopted and has not yet made a legally enforceable commitment to adopt and implement. Such emission reductions are "further" reductions under CAA section 202(i). In some cases, therefore, we are considering an area to need further reductions in order to attain and maintain and also proposing to approve its attainment demonstration. Before we take final and unconditional action on an attainment demonstration in such a case, the state will have to adopt all the necessary rules or make enforceable commitments to adopt them.

<sup>&</sup>lt;sup>19</sup> Our recent proposals on the SIPs explain how we propose to approach the approval of 1-hour attainment SIPs themselves with respect to the NOx SIP Call. To summarize, we have proposed to approve a SIP which assumes implementation of the NOx SIP Call provided that the state is committed to implementing the NOx reductions within the in-state portion of the modeling domain of the subject nonattainment area. Reductions outside the domain and in other states may be assumed even if a commitment is currently lacking for those areas.

These state-specific findings are not final and we are not making them final via the Tier 2 rulemaking. In our final actions on these SIP revisions we may deviate from our proposal for one or more areas, based on the full record of the rulemaking for each, including any comments received after today. However, we have used the ozone attainment assessments as described summarized below in making our Tier 2 determination on the need for additional emission reductions in these areas.

As result of EPA's review of the states' SIP submittals, EPA believes that the ozone modeling submitted by the applicable states for the Chicago, IL; Milwaukee, WI; Greater CT (Hartford and New London metropolitan areas); and Western MA areas demonstrate attainment through the control measures contained in the submitted attainment strategy. We expect that Illinois, Wisconsin, and Indiana will submit further SIP revisions for Chicago and Milwaukee prior to our taking final action on our recent proposals regarding the submissions they made earlier. These new revisions will be based on a new round of modeling conducted by the Lake Michigan Air Directors Consortium (LADCO) on behalf of the states. While we have not received this modeling, we have received a progress report on it.<sup>13</sup>

While Michigan was not required to submit attainment demonstrations for the Benton Harbor and Grand Rapids-Muskegon areas, the ozone modeling submitted and weight of evidence analysis performed for the attainment demonstrations submitted in 1998 for Chicago and Milwaukee indicates that these two areas will also be in attainment in 2007 based only on emission reductions which come from measures which are already adopted and legally enforceable.

For the New York Metro area, Philadelphia, Baltimore, District of Columbia, and Houston nonattainment areas, the EPA has proposed to determine that additional emission reduction beyond those provided by the SIP submission are necessary for attainment. A portion of that reduction will be achieved by EPA's Tier 2/Sulfur program. In the case of Washington DC, our analysis indicates that the Tier 2/Sulfur program will provide all of the additional emission reductions needed to attain.

Atlanta's statutory attainment date as a serious 1-hour ozone nonattainment area was November 1999, which it has not met. Georgia has requested an attainment date extension for Atlanta to November 15, 2003 and has proposed an emission control program to achieve attainment by that date. The EPA has proposed to assign Atlanta an attainment date of November 2003 based on a successful demonstration by the State that the control strategy described in the SIP will achieve attainment by this date. However, many of the measures in that strategy are not yet adopted or fully committed, and are therefore "further" reductions under 202(i). It is clear from the amount of emission reductions from these measures that the nonattainment status of Atlanta would extend into the 2004 and later period if only "previous" emission reductions were considered. The modeling for Atlanta assumed implementation of the NOx SIP Call outside the local modeling domain, but lesser NOx reductions within the domain.

This is an issue, since the full NOx reductions from the SIP call are considered "previous" in connection with the Tier 2 rulemaking. However, the difference in NOx reduction within the modeling domain is small, and it is apparent that even if the full NOx reductions from the SIP call had been assumed attainment would still be impossible without reductions from measures which are "further" reductions for purposes of the Tier 2 determinations.

The specific reasons for reaching these conclusions are explained in the individual Federal Register notices.

#### e. Other Local Ozone Modeling

We have received ozone modeling for the Beaumont-Port Arthur nonattainment area.<sup>14</sup> Beaumont-Port Arthur is a moderate ozone nonattainment area which failed to attain by its November 15, 1996 deadline. Presently, the state of Texas is seeking our approval for a demonstration that Beaumont-Port Arthur is impacted by ozone transport from the Houston area, in order to support a request that we extend its attainment deadline to 2007 which would be the same as the deadline for Houston. We proposed action on this request on April 16, 1999 (64 FR 18864) and extended the comment period on June 3, 1999 (64 FR 29822). The modeling analysis indicates nonattainment in 2007 even under an emissions scenario that includes reductions that must be considered "further emission reductions" under CAA section 202(i).

We have also recently become aware of recent modeling by the state of Texas for the Dallas-Fort Worth metropolitan area. Dallas has failed to meet its 1999 deadline for attainment Texas has made known its intent to seek an attainment date extension for this area. We have recently indicated to Texas that we will propose to approve its request for an attainment date extension to 2007, provided that the state can meet several necessary conditions one of which is to demonstrate attainment by that date. The state is conducting modeling analysis to identify its options for reaching attainment in Dallas by 2007. This modeling has been made public, and summaries of it have been put in the docket for this rulemaking. The modeling results to date indicate that even with the emission reductions from the Tier 2/Sulfur program, Dallas will be in nonattainment in 2007. This clearly demonstrates further reductions in emissions under CAA section 202(i) are needed to attain and maintain in this area.

We have not received any recent ozone modeling from California, because California submitted and we approved the SIPs for nonattainment areas in California some time ago, before our proposal for the Tier 2/Gasoline Sulfur program. However, the air quality situation and a recent SIP revision for one area in California support the conclusion that there is an overall need for further reductions in order to attain and maintain.

It is appropriate for us to consider the need for further emission reductions in order for areas in California to attain and maintain. California contains many of the most ozone-impacted areas in the nation. According to California, about 7 to 10 percent of all car and light truck travel

in California takes place in vehicles originally sold outside of California. Nine areas in California currently designated as nonattainment (and two counties currently designated as being in attainment) with a population of approximately 30 million have 1996-1998 design values above the 1-hour ozone NAAQS. Seven of the nonattainment areas have approved SIPs, including demonstrations of attainment for their required dates. The approved demonstrations did not depend on any reductions in emissions from more stringent standards for cars sold outside California, having been prepared prior to our proposal for these standards.

However, the state of California has recently filed an update to its State Implementation Plan for the South Coast Air Basin that expressly claims that the Tier 2 program will lead to four tons of reduced NOx emissions per day in the South Coast area in 2010, and includes this reduction in the attainment strategy for the area. <sup>16</sup> The four tons per day NOx reductions cited represents only a small fraction of the emission reductions needed in the South Coast to attain the NAAQS.

The state is developing yet another revision to the South Coast plan, which we understand will also depend in part on the emission reductions from Tier 2 vehicles originally sold out of state. We expect that California will be submitting one or more similar revisions including emission reductions from Tier 2 standards for some other areas, since it appears that some serious classification nonattainment areas in California with an attainment deadline of 1999 have not met that date. These areas are San Diego and the San Joaquin Valley. San Joaquin has had too many exceedances to be eligible for an extension other than through reclassification to severe or through an attainment extension based on overwhelming transport from an area with a later attainment date, while San Diego appears to be eligible for a 1-year attainment date extension under the provisions of CAA section 181(a)(5). We have not yet received an indication of California's intention in this regard, or any modeling which assesses whether these areas can attain before 2004 relying only on baseline measures with respect to CAA section 202(i)

Attainment of the 1-hour standard in the South Coast Air Basin, Southeast Desert, Sacramento, and Ventura nonattainment areas by their future attainment dates (2010 for the South Coast, 2007 for Southeast Desert, and 2005 for Sacramento and Ventura) remains the goal of California and EPA, but will be a challenging task. The difficulty of the task is reflected in ongoing litigation and settlement negotiations over both the design and the implementation of the attainment plans in the South Coast, for example. We believe that there is a possibility that some of these areas would not attain on schedule if we were not adopting the new standards for cars and light trucks, and the sulfur limits for gasoline sold outside of California.

#### f. Need for Further Reductions in Emissions in Order to Attain and Maintain

After considering the results of the exceedance method applied to the ozone concentrations predicted by the EPA ozone modeling described in Sections III.B.1,2, and 3, and

the conclusions from our review of the local ozone modeling described above, we determined which areas are certain or highly likely to require further reductions to attain and maintain, under the meaning of CAA section 202(i). Table III.B-1 in the preamble lists these areas.

We first considered all areas with predicted 2007 nonattainment according to the exceedance method applied to the EPA ozone modeling.

Areas which did not have a 1-hour ozone design value above the NAAQS in at least one of the 1995 to 1997 and 1996 to 1998 periods are not considered to be certain or highly likely to need further reductions, regardless of predictions of exceedances in our modeling. However, there were six areas predicted in the EPA modeling to have exceedances in 2007 which had design values of 90 to 100 percent of the NAAQS in at least one of these two periods. We consider these to have moderate risk of failing to attain and maintain without further emission reductions because meteorological conditions may be more severe in the future. These are Biloxi, Cleveland, Detroit, New Orleans, Pensacola, and Tampa.

Next, for Chicago, Milwaukee, and Greater Connecticut (Hartford and New London) we considered the SIP's successful demonstration of attainment relying only on baseline measures to be a sufficient reason not to consider these areas to be certain or highly likely to need further reductions. However, because of modeling uncertainties and the fact that these SIPs did not consider attainment and maintenance beyond the attainment date, we consider these areas to have a significant individual risk of failing to attain and maintain. Benton Harbor and Grand Rapids-Muskegon are included in this characterization also.

Because the SIP modeling analysis and the EPA exceedance method agreed on the nonattainment prospects for Houston, New York, Philadelphia, Baltimore, Atlanta, and Washington DC, excluding measures which would provide "further" reductions, we consider these to be certain or highly likely to require further emission reductions in order to attain and maintain the 1-hour ozone NAAQS.

Because the EPA modeling for Dallas did not successfully reproduce exceedances which actually occurred in 1995 we considered it at best inconclusive. The local modeling supports our conclusion that Dallas is certain or highly likely to need further reductions to attain and maintain.

Because the episode days in the EPA modeling did not include any on which Beaumont-Port Arthur experiences exceedances, yet exceedances have been observed, we considered the EPA modeling at best inconclusive. The local modeling led us to conclude that Beaumont-Port Arthur is certain or highly likely to need further reductions to attain and maintain. We included the Los Angeles-Riverside-San Bernardino CMSA (South Coast Air Basin) in this category as well, based on its reliance on Tier 2 reductions in its most recent SIP submittal.

#### C. Particulate Matter and Visibility/Regional Haze

#### 1. Particulate Matter

## a. Background on Particulate Matter

Particulate matter (PM) represents a broad class of chemically and physically diverse substances that exist as discrete particles (liquid droplets or solids) over a wide range of sizes. The NAAQS that regulates PM addresses only PM with a diameter less than 10 microns, or PM<sub>10</sub>. The coarse fraction of PM<sub>10</sub> are those particles which have a diameter in the range of 2.5 to 10 microns, and the fine fraction being those particles which have a diameter less than 2.5 microns, or PM<sub>2.5</sub>. These particles and droplets are produced as a direct result of human activity and natural processes, and they are also formed as secondary particles from the atmospheric transformation of emissions of SOx, NOx, ammonia, and VOCs.

Natural sources of particles in the coarse fraction of  $PM_{10}$  include windblown dust, salt from dried sea spray, fires, biogenic emanation (e.g., pollen from plants, fungal spores), and volcanoes. Fugitive dust and crustal material (geogenic materials) comprise approximately 80 percent of the coarse fraction of the  $PM_{10}$  inventory as estimated by methods in use today. Manmade sources of these coarser particles arise predominantly from combustion of fossil fuel by large and small industrial sources (including power generating plants, manufacturing plants, quarries, and kilns), wind erosion from crop land, roads, and construction, dust from industrial and agricultural grinding and handling operations, metals processing, and burning of firewood and solid waste. Coarse-fraction  $PM_{10}$  remains suspended in the atmosphere a relatively short period of time.

Most of the emission sources listed for coarse particles also have a substantial fine particle fraction. Their share of the  $PM_{2.5}$  inventory is reduced somewhat, however, because of the role of other sources that give rise to primarily  $PM_{2.5}$ . The other sources of  $PM_{2.5}$  include carbon-based particles emitted directly from gasoline and diesel internal combustion engines, and a large component of secondary sulfate-based particles (formed from SOx and ammonia), nitrate-based particles (formed from NOx and ammonia), and carbonaceous secondary particles (formed through transformation of VOC emissions).  $PM_{2.5}$  from fugitive dust and crustal sources (geogenic materials) comprise approximately one-half of the directly emitted  $PM_{2.5}$  inventory, substantially less than their share of coarse PM emissions. The presence and magnitude of

<sup>&</sup>lt;sup>20</sup> There is evidence from ambient studies that emissions of these materials may be overestimated and/or that once emitted they have less of an influence on monitored PM concentrations than this inventory share would suggest.

crustal PM<sub>2.5</sub> in the ambient air is much lower even than suggested by this smaller inventory share, due to the additional presence of secondary PM from non-crustal sources and the removal of a large portion of crustal emissions close to their source. This near-source removal is a result of the lack of inherent thermal buoyancy, low release height, and interaction with their surroundings (impaction and filtration by vegetation).<sup>17</sup>

Secondary PM is dominated by sulfate particles in the eastern U.S. and parts of the western U.S., with nitrate particles and carbonaceous particles dominant in some western areas. Mobile sources can reasonably be estimated to contribute to ambient secondary nitrate and sulfate PM in proportion to their contribution to total NOx and SOx emissions. (EPA 1998, p. 44-45)

The sources, ambient concentration, and chemical and physical properties of  $PM_{10}$  vary greatly with time, region, meteorology, and source category. A first step in developing a plan to attain the  $PM_{10}$  NAAQS is to disaggregate ambient  $PM_{10}$  into the basic categories of sulfate, nitrate, carbonaceous, and crustal, and then determine the major contributors to each category based on knowledge of local and upwind emission sources. Following this approach, SIP strategies to reduce ambient PM concentrations have generally focused on controlling fugitive dust from natural soil and soil disturbed by human activity, paving dirt roads and controlling of soil on paved roads, reducing emissions from residential wood combustion, and controlling major stationary sources of  $PM_{10}$  where applicable. The control programs to reduce stationary, area, and mobile source emissions of sulfur dioxide, oxides of nitrogen, and volatile organic compounds in order to achieve attainment with the sulfur dioxide and ozone NAAQS also have contributed to reductions in the fine fraction of  $PM_{10}$  concentrations. In addition, the EPA standards for PM emissions from highway and nonroad engines are contributing to reducing  $PM_{10}$  concentrations. As result of all these efforts, in the last ten years, there has been a downward trend in  $PM_{10}$  concentrations, with a leveling off in the later years. (EPA 1998, p. 38)

Scientific studies have linked particulate matter (alone or in combination with other air pollutants) with a series of health effects. Coarse particles can accumulate in the respiratory system and aggravate health problems such as asthma. Particles in motor vehicle exhaust emissions and the particles formed by the transformation of motor vehicle gaseous emissions tend to be in the fine particle range. Fine particles penetrate deeply into the lungs and are more likely than coarse particles to contribute to a number of the health effects. These health effects include premature death and increased hospital admissions and emergency room visits, increased respiratory symptoms and disease, decreased lung function, and alterations in lung tissue and structure and in respiratory tract defense mechanisms. Children, the elderly, and people with cardiopulmonary disease, such as asthma, are most at risk from these health effects. PM also causes damage to materials and soiling. It is a major cause of substantial visibility impairment in many parts of the U.S.

These effects are discussed further in EPA's "Staff Paper" and "Air Quality Criteria

Document" for particulate matter.<sup>19</sup>

There is additional concern regarding the health effects of PM from diesel vehicles, apart from the health effects which were considered in setting the NAAQS for PM<sub>10</sub> and PM<sub>2.5</sub>. Diesel PM contains small quantities of chemical species that are known carcinogens, and diesel PM as a whole has been implicated in occupational epidemiology studies. We have considered these studies, and EPA's Office of Research and Development has recently submitted to a committee of our Science Advisory Board a draft assessment document which contains a proposed conclusion that diesel exhaust is a highly likely human cancer hazard and is a potential cause of other nonmalignant respiratory effects. The scientific advisory committee has met to discuss this document, and we are awaiting written review comments from the committee. We expect to submit a further revision of the document to the advisory committee before we make the document final.

# b. PM<sub>10</sub> Role of Cars and Light Trucks

Section A of this Chapter presents the estimates of PM emissions that were used for this rulemaking. PM emissions from mobile sources were estimated with newly developed models. PM emissions from other source categories were those from the most recent National Emissions Trends inventory process. Estimates of emissions were prepared at the county level, and then aggregated to higher levels for purposes of presentation.

The contribution of cars and light trucks to ambient  $PM_{10}$  concentrations can be assessed in simple fashion by comparing the estimates of direct  $PM_{10}$  emissions and of  $PM_{10}$  precursors emissions. This approach is subject to the uncertainties in those emission estimates, which can be large for many types of natural and stationary sources, and to uncertainties attributable to disregard for the locations and temporal patterns of emissions. An alternative approach to assessing role is to begin with measurements of the quantity and chemical identity of  $PM_{10}$  material collected on ambient filters, and apportion that material to sources based on the chemical identity of their emissions. The organic portion of  $PM_{10}$  can be analyzed for dozens of specific tracer compounds, allowing it to be apportioned with more sophistication. It is necessary to use estimates of inventory shares to apportion a single chemical class which has no tracer back to source type, for example sulfate  $PM_{10}$ .

Because of the current interest in PM<sub>2.5</sub>, most recent ambient-based source apportionment studies have focused on PM<sub>2.5</sub>. Since virtually all of the PM<sub>10</sub> attributable to cars and light trucks is also PM<sub>2.5</sub>, estimates of the mass concentration of PM<sub>2.5</sub> due to cars and trucks from these studies can be treated as estimates of PM<sub>10</sub> as well. The 1997 Air Quality Trends Report presents a summary assessment based on studies across the country. Most of these studies identified PM composition only down to the nitrate/sulfate/crustal/carbonaceous level, requiring apportionment within each to be based on emission inventory estimates. In contrast, a recent

study in Denver made use of detailed analysis of the organic compounds within the carbonaceous fraction.

The Northern Front Range Air Quality Study (NFRAQS) report collected numerous ambient PM<sub>2.5</sub> samples in various areas around Denver, including urban areas such as Welby and rural areas such as Brighton, during the winter of 1997. <sup>20</sup> The samples were analyzed for their composition, including the contribution of carbon-based, sulfate, nitrate, and crustal matter particles to each sample. The results of that analysis are summarized in Table III.C-1.

Site Carbon-based Sulfate-based Nitrate-based Crustal Matter  $PM_{2.5}$  $PM_{25}$  $PM_{25}$  $PM_{2.5}$ Welby 49% 10% 25% 16% Brighton 42% 15% 32% 11%

Table III.C-1. NFRAQS Compositional Analysis of PM<sub>2.5</sub> Samples

The study used a variety of techniques to determine how much of the carbon-based, sulfate, and nitrate PM found in the PM<sub>2.5</sub> samples came from gasoline vehicles. Organic tracer compounds were used to determine how much of the carbonaceous PM<sub>2.5</sub> came from gasoline vehicles and to separate the contribution of normal emitting vehicles and higher emitting vehicles. A combination of inventory analysis, dispersion modeling, atmospheric chemistry, and analysis of compositional variation over time were used to determine the contribution of gasoline vehicles to sulfate and nitrate PM<sub>2.5</sub>. The study reported the following average percentages of sulfates and nitrates coming from gasoline vehicles. The proportion of each type of PM<sub>2.5</sub> determined to come from gasoline vehicles is shown in Table III.C-2.

Table III.C-2. Percentage of PM<sub>2.5</sub> Coming from Gasoline Vehicles

Site	Carbon-Based	Sulfate-Based	Nitrate-Based
Welby	57%	20%	36%
Brighton	62%	14%	38%

From these two sets of numbers, one can calculate the contribution of each type of  $PM_{2.5}$  from gasoline vehicles to total  $PM_{2.5}$ , as shown in the middle three columns of Table III.C-3. The results can be summed to derive the contribution of gasoline vehicles to total  $PM_{2.5}$ , as shown in the last column in Table III.C-3.

Table III.C-3. Percentage of Total PM<sub>2.5</sub> From Gasoline Vehicles

Site	Carbon-Based	Sulfate-Based	Nitrate-Based	Total
Welby	28%	2%	9%	39%
Brighton	26%	2%	12%	40%

These results shown here within each  $PM_{2.5}$  chemical fraction may be typical of urban areas, while the ratios between the chemical fractions may vary by area. Virtually all direct and secondary PM from gasoline vehicles is  $PM_{2.5}$ . The percentage contribution of gasoline vehicles to  $PM_{10}$  concentrations would be lower than for  $PM_{2.5}$ , after accounting for the crustal material PM and coarse-fraction PM from all sources.

A summary of several studies of the PM contribution, including the NFRAQS study just summarized, is given in Table III.C-4. The table also shows the researchers' estimate of the absolute contribution of gasoline vehicles to ambient PM.. This ranges to as high as about 8  $\mu$ g/m³. The annual PM<sub>10</sub> NAAQS is 50  $\mu$ g/m³ and the 24-hour NAAQS is 150  $\mu$ g/m³. On a percentage basis, gasoline vehicles can therefore contribute up to about 5 to 15 percent of the ambient loading allowed by the PM<sub>10</sub> NAAQS. These findings for the most part apply to urban areas. In rural areas with less vehicle travel and/or better dispersion conditions the contribution would be less.

Source apportionment studies of the type summarized here have also addressed the contribution of diesel vehicles to ambient PM, but at the present time virtually all diesel PM is from vehicle classes other than cars and light trucks. The draft Health Assessment Document for Diesel Emissions contains a table similar to Table III.C-4 but for diesel PM contributions to ambient PM concentrations. This table is reproduced here as Table III.C-9, and discussed later in the context of the possibility of increased sales of diesel cars and light trucks.

Table III.C-4. Gasoline Vehicle/Engine Contribution to Ambient PM - from source apportionment reports

Author (Reference)	Year of Sampling, No. days	Location Type	Source Profile Used	Location	Total PM2.5 (stdev), µg/m³	Gas PM2.5 (stdev), µg/m³
Friedlander, 1973 <sup>21</sup>	1969, 1 day	Urban	EC, OC total, Elements	Pasadena	nr	8.2% of aerosol mass**
Gartrell and Friedlander, 1974 <sup>22</sup>	Sept/Oct 1972 1 day each site		EC, OC total, Elements, Major Ions	Pasadena Pomona Riverside Fresno San Jose	64 (7) 180 (20) 125 (14) 207 (23) 189 (21)	5.1 (0.15) 7.2 (0.3) 3.9 (0.15) 2.2 (0.1) 8.3 (0.33)
Schauer et al., 1996 Southern California <sup>23</sup>	1982, 60 days (one every sixth day)	Urban Urban Suburban Urban	OC Species, EC, Elements	West LA Pasadena Rubidoux Downtown LA	24.5 (2.0) 28.2 (1.9) 42.1 (3.3) 32.5 (2.8)	1.44 (0.16 ) 1.63 (0.20) 0.34 (0.05) 2.12 (0.23)
Lowenthal et al., 1992 <sup>24</sup>	1989, 59 days (one every sixth day)		EC, OC total, Elements, Major Ions	Santa Barbara, CA	36.5*	4.0 (2.2)*
Wittorff,1994 <sup>25</sup>	Spring, 1993, 3 days	Urban Bus Stop	EC, OC total, Elements, Major Ions	Manhattan, NY	35.8-83.0*	4.2 (avg) 7% of total PM on average
NFRAQS, 1998	Winter, 1996-97, 60 days	Urban Suburban	OC Species, EC, Elements, Major ions	Welby, CO Brighton, CO	16.7 12.4	6.51 (39%) 3.35 (27%)

\*PM10, \*\*TSP? † Not available

nr=not reported

OC: Organic Carbon EC: Elemental Carbon

Major Ions: nitrate, sulfate, chloride and in some cases ammonium, sodium, potassium

## c. Current PM<sub>10</sub> Nonattainment

PM<sub>10</sub> attainment status for the period 1996-1998 was developed through an analysis of data obtained from the Aerometric Information Retrieval System (AIRS) on October18, 1999. The attainment determination was based on the concepts outlined for the pre-existing National Ambient Air Quality Standards (NAAQS), and represent an exceedance-based form of the standard. <sup>26</sup> The PM<sub>10</sub> NAAQS has a requirement that an area conducting 1 in 6 day sampling increase sampling frequency to daily frequency upon recording a violation. If this procedure is not followed, then an "estimate" of the number of exceedances expected is calculated for that year. Some areas considered nonattainment in this recent analysis have fewer than four actual monitored 24-hour exceedances. The analysis was not subjected to a review by the EPA Regional Offices, who have an important role in verifying and validating these data. The analysis therefore represents an upper bound of the number of areas that could potentially be in violation of the 1987 PM<sub>10</sub> NAAQS.

The most recent  $PM_{10}$  monitoring data indicates that 15 designated  $PM_{10}$  nonattainment counties, with a population of almost 9 million in 1996, violated the  $PM_{10}$  NAAQS in the period 1996-1998. The areas that are violating do so because of exceedances of the 24-hour  $PM_{10}$  NAAQS. No areas had monitored violations of the annual standard in this period. Table III.C-5 lists the 15 counties. The table also indicates the classification for each area and the status of our review of the State Implementation Plan. SIP status was obtained from an EPA data base based on Federal Register actions. Maricopa County, AZ, did have an approved SIP as a moderate  $PM_{10}$  nonattainment area. It has been reclassified as a serious area, and has not received approval for serious area SIP requirements.

Although we do not believe that we are limited to considering only designated nonattainment areas in implementing CAA section 202(i), we have focused on the designated areas in the case of PM<sub>10</sub>. An official designation of PM<sub>10</sub> nonattainment indicates the existence of a confirmed PM<sub>10</sub> problem that is more than a result of a one-time monitoring upset or a results of PM<sub>10</sub> exceedances attributable to natural events. In addition to these designated nonattainment areas, there are 15 unclassified counties in 12 geographically spread out states, with a 1996 population of over 4 million, for which the state has reported PM<sub>10</sub> monitoring data for this period indicating a PM<sub>10</sub> NAAQS violation. We have not yet excluded the possibility that a one-time monitoring upset or a natural event(s) is responsible for the monitored violations in 1996-1998 in the 15 unclassified counties. We adopted a policy in 1996 that allows areas whose PM<sub>10</sub> exceedances are attributable to natural events to remain unclassified if the state is taking all reasonable measures to safeguard public health regardless of the source of PM<sub>10</sub> emissions. The policy was reiterated after the PM NAAQS were revised. 27 Areas that remain unclassified areas are not required to submit attainment plans, but we work with each of these areas to understand the nature of the PM<sub>10</sub> problem and to determine what best can be done to reduce it. The Tier 2/Gasoline Sulfur program will reduce PM<sub>10</sub> concentrations in these 15 unclassified counties, because all have car and light truck travel that contributes to PM<sub>10</sub> and

precursor emissions loadings. This reduction will assist these areas in reducing their  $PM_{10}$  nonattainment problem, if a problem is confirmed upon closer examination of each local situation.

Boise, ID, had also been classified as a  $PM_{10}$  nonattainment area at one time and was monitored to have a  $PM_{10}$  NAAQS violation in 1996-1998. However, the pre-existing  $PM_{10}$  NAAQS does not presently apply in Boise, ID, because in the period between our revision of the old  $PM_{10}$  NAAQS and the Court's decision to vacate the revised  $PM_{10}$  NAAQS, we determined that Boise was in attainment with the old  $PM_{10}$  NAAQS and that it therefore no longer applied in that area.

Table III.C-5. Fifteen PM<sub>10</sub> Nonattainment Areas Violating the PM<sub>10</sub> NAAQS in 1996-1998

Area	Classification	sIP Approved?	1996 Population (millions)
Clark Co., NV	Serious	No	0.93
El Paso, TX	Moderate	Yes	0.67
Gila, AZ	Moderate	No	0.05
Imperial Co., CA	Moderate	No	0.14
Inyo Co., CA	Moderate	No	0.02
Kern Co., CA	Serious	No	0.62
Mono Co., CA	Moderate	No	0.01
Kings Co., CA	Serious	No	0.11
Maricopa Co., AZ	Serious	No	2.61
Power Co., ID	Moderate	No	0.01
Riverside Co., CA	Serious	No	1.41
San Bernardino Co., CA	Serious	No	1.59
Santa Cruz Co., AZ	Moderate	No	0.04
Tulare Co., CA	Serious	No	0.35
Walla Walla Co., WA	Moderate	Yes	0.05
		TOTAL POPULATION	8.61

#### d. Future Nonattainment

Because the types and sources of  $PM_{10}$  are complex and vary from area to area, the best projections of future  $PM_{10}$  concentrations are the local emission inventory and air quality modeling analyses that states have developed or are still in the process of developing for their  $PM_{10}$  attainment plans. We do employ a modeling approach, known as the source-receptor matrix approach, for relating emission reductions to  $PM_{10}$  reductions on a national scale. This

approach is one of our established air quality models for purposes of quantifying the health and welfare related economic benefits of PM reductions from major regulatory actions. One application of this modeling approach was for the Regulatory Impact Analysis for the establishment of the new PM NAAQS.<sup>28</sup> This model is also the basis for the estimates of PM<sub>10</sub> (and PM<sub>2.5</sub>) concentrations reductions we have used to estimate the economic benefits of the Tier 2/Gasoline Sulfur program in 2030. Its use for this purpose is described in the final RIA for the Tier 2/Gasosline Sulfur rule. In both applications, we modeled an emissions scenario corresponding to controls currently in place or committed to by states. As such, this scenario is an appropriate baseline for determining if further reductions in emissions are needed in order to attain and maintain the PM<sub>10</sub> NAAQS.

In the RIA for the establishment of the PM NAAQS, we projected that in 2010 there will be 45 counties not in attainment with the original  $PM_{10}$  NAAQS. We cited these modeling results in our proposal for the Tier 2/Gasoline Sulfur program and in our first supplemental notice. After reviewing public comments on our presentation of these modeling results, we have concluded that while the source-receptor matrix approach is a suitable model for estimating PM concentration reductions for economic benefits estimation, it is not a tool we can use with high confidence for predicting that individual areas that are now in attainment will become nonattainment in the future. However, we believe the source-receptor matrix approach is appropriate for, and is a suitable tool for, determining that a current designated nonattainment area has a high risk of remaining in  $PM_{10}$  nonattainment at a future date. Therefore, we have cross-matched the results for 2030 from our final RIA for Tier 2 and the list of current  $PM_{10}$  nonattainment areas with monitored violations in 1996 to 1998 shown in Table III.C-5.

Based on this modeling, we conclude that the 8 classified nonattainment areas shown in Table III.C-6 have a high risk of failing to attain and maintain without further emission reductions. These areas have a population of nearly 8 million. Included in the group are the counties that are part of the Los Angeles, Phoenix, and Las Vegas metropolitan areas, where traffic from cars and light trucks is substantial. California areas will benefit from the Tier 2/Gasoline Sulfur program because of travel within California by vehicles originally sold outside the state, and by reduced poisoning of catalysts from fuel purchased outside of California.

We used the more recent modeling for 2030 rather than the earlier modeling for 2010, because the modeling for 2030 incorporates more recent estimates of emissions inventories. Our emission estimates in our final RIA indicate that PM<sub>10</sub> emissions under the baseline scenario increase steadily between 1996 and 2030, for 47 states combined and for four specific cities, suggesting that areas in nonattainment in both 1996-1998 and 2030 will be in nonattainment in the intermediate years as well assuming no further emission reductions. A factor tending to make Table III.C-6 shorter is that we have not relied on the source-receptor matrix model's prediction of 24-hour nonattainment, as those predictions on an individual area basis are less reliable than the predictions of annual average nonattainment.

Table III.C-6. Eight areas with a high risk of failing to attain and maintain the  $PM_{10}$  NAAQS without further reductions in emissions.

Area		1996 Population (millions)
Clark Co., NV		0.93
Imperial Co., CA		0.14
Kern Co., CA		0.62
Kings Co., CA		0.11
Maricopa Co., AZ		2.61
Riverside Co., CA		1.41
San Bernardino Co., CA		1.59
Tulare Co., CA		0.35
	TOTAL POPULATION	7.76

Taken together and considering their number, size, and geographic distribution, these 8 areas are sufficient to establish the case that additional reductions are needed in order to attain and maintain the PM<sub>10</sub> NAAQS. This determination provides additional support for the NOx and VOC standards and for the limits on gasoline sulfur, which are also fully supported on ozone attainment and health effects considerations. The sulfate particulate, sulfur dioxide, NOx, and VOC emission reductions from the Tier 2/Gasoline Sulfur program will help the 8 areas in Table III.C-2 to attain and maintain the PM<sub>10</sub> NAAQS. The new PM standards for gasoline and diesel vehicles is also supported by this PM<sub>10</sub> determination. We are also establishing the new PM standard today to avoid the possibility that PM<sub>10</sub> concentrations in these and other areas do not actually get worse due to an increase in sales of diesel vehicles, which could create a need for further reductions which would be larger and would affect more areas of the country.

Table III.C-6 is limited to designated  $PM_{10}$  nonattainment areas which both had monitored violations of the  $PM_{10}$  NAAQs in 1996-1998 and are predicted to be in nonattainment in 2030 in our  $PM_{10}$  air quality modeling. This gives us high confidence that these areas require further emission reductions to attain and maintain, but does not fully consider the possibility that there are other areas which are now meeting the  $PM_{10}$  NAAQS which have at least a significant probability of requiring further reductions to continue to maintain it. Our air quality modeling predicted 2030 violations of the annual average  $PM_{10}$  NAAQS in five additional counties that in either 1997 or 1998 had single-year annual average monitored  $PM_{10}$  levels of at least 90 percent of the NAAQS, but did not exceed the formal definition of the NAAQS over the three-year period ending in 1998. These areas were identified from the most recent published EPA Air Quality Trends Report (USEPA 1998) and from tables that have been prepared for inclusion in the next update of the Air Quality Trends report.<sup>29</sup> In two of these areas, New York Co., NY and Harris Co., TX, the average  $PM_{10}$  level in 1998 was above the 50  $\mu g/m^3$  value of the

NAAQS. These two areas are not included in the Table III.C-6 list of 15 areas with a high risk of failing to attain and maintain because lower  $PM_{10}$  levels in 1996 and 1997 caused their three-year average  $PM_{10}$  level to be lower than the NAAQS.

These five areas were listed based on their second high 24-hour concentration and annual average concentration in 1997 or 1998 only. Actual nonattainment determinations are made based on three years of data, and on estimates of expected exceedances of the 24-hour standard. The second-high 24-hour  $PM_{10}$  level in 1998 is only an approximate surrogate for the outcome of an expected exceedances calculation since other years of data and the frequency of monitor operation would also enter the calculation.

The five additional counties are shown in Table III.C-7. They have a combined population of almost 17 million, and a broad geographic spread. Unlike the situation for ozone, for which precursor emissions are generally declining over the next 10 years or so before beginning to increase, we estimate that emissions of PM<sub>10</sub> will rise steadily unless new controls are implemented. The small margin of attainment which these areas currently enjoy will likely erode; the PM air quality modeling suggests that it will be reversed. We therefore consider these areas to each individually have a significant risk of failing to maintain the NAAQS without further emission reductions. There is a substantial risk that at least some of them would fail to maintain without further emission reductions. The emission reductions from the Tier 2/Gasoline Sulfur program will help to keep them in attainment.

Table III.C-7. Five areas with a significant risk of failing to attain and maintain the  $PM_{10}$  NAAQS without further reductions in emissions

	Area	1996 Population (millions)
New York Co., NY		1.33
Cuyahoga Co., OH		1.39
Harris, Co., TX		3.10
San Diego Co., CA		2.67
Los Angeles Co., CA		8.11
	TOTAL POPULATION	16.6

In addition to the counties already listed in Tables III.C-5 and III.C-7, there are other areas for which 1997 and 1998 data indicate that maintenance of the  $PM_{10}$  NAAQS is at risk, particularly if diesel sales of cars and light truck increase as discussed below. Table III.C-8 lists additional counties for which either 1997 or 1998 monitoring data, or both, indicated a second-high  $PM_{10}$  concentration for the single year within 10 percent of the  $PM_{10}$  24-hour NAAQS or an annual average  $PM_{10}$  concentration within 10 percent of the annual average  $PM_{10}$  NAAQS. Our

Source-Receptor Matrix modeling of annual average  $PM_{10}$  concentrations in these areas did not indicate nonattainment in 2030, but the margin of attainment they currently enjoy is small. Only counties which are part of metropolitan statistical areas are listed in Table III.C-8, in order to focus on those in which traffic densities are high. Considering both the annual and 24-hour NAAQS, there were 13 areas within 10 percent of the standard.

Table III.C-8. Thirteen metropolitan statistical area counties with 1997 and/or 1998 ambient  $PM_{10}$  concentrations within 10 percent of the annual or 24-hour the  $PM_{10}$  NAAQS.\*

	1996 Population
	(millions)
Areas within 10 percent of the annual PM <sub>10</sub> NAAQS	
Lexington Co., SC	0.20
Union Co., TN	0.02
Washoe Co., NV	0.30
Madison Co., IL	0.26
Dona Ana Co., NM	0.16
El Paso Co., TX	0.68
Ellis Co., TX	0.97
Fresno Co., CA	0.74
Philadelphia Co., PA	1.47
Areas within 10 percent of the 24-hour PM <sub>10</sub> NAAQS	
Lexington Co., SC	0.20
El Paso Co., TX	0.68
Union Co., TN	0.02
Mobile Co., AL	0.40
Dona Ana Co., NM	0.16
Lake Co., IN	0.48
Philadelphia Co., PA	1.47
Pennington Co., SD	0.09
Ventura Co., CA	0.71
TOTAL POPULATION OF ALL 13 AI	REAS 6.48

<sup>\*</sup> These areas are listed based on their second high 24-hour concentration and annual average concentration in 1997, 1998, or both. Official nonattainment determinations are made based on three years of data, and on estimates of expected exceedances of the 24-hour standard.

#### e. Diesel PM

At the present time, virtually all cars and light trucks being sold are gasoline fueled. The ambient PM<sub>10</sub> air quality data for 1996 to 1998 reflects that current situation, and the predictions of future PM<sub>10</sub> air quality are based on an assumption that this will continue to be true. However, we are concerned over the possibility that diesels will become more prevalent in the car and light-duty truck fleet, since automotive companies have announced their desire to increase their sales of diesel cars and light trucks. As current diesel vehicles emit higher levels of PM<sub>10</sub> than gasoline vehicles, a larger number of diesel vehicles could dramatically increase levels of exhaust PM<sub>10</sub>, especially if more stringent standards are not in place. The new PM standards will ensure that an increase in the sales of diesel cars and light trucks will not increase PM emissions from cars and light trucks so substantially as to endanger PM<sub>10</sub> attainment and maintenance on a more widespread basis. Given this potential, it is appropriate to establish the new PM standards now on the basis of the increase in sales of diesel vehicles being a reasonable possibility without such standards. Establishing the new PM standards now avoids the public health impact and industry disruption that could result if we waited until an increase in sales of diesels with high PM emissions had already occurred.

In order to assess the potential impact of increased diesel sales penetration on PM emissions, we analyzed the increase in PM<sub>10</sub> emissions from cars and trucks under a scenario in which the use of diesel engines in cars and light trucks increases. We used projections developed by A.D. Little, Inc. as part of a study conducted for the American Petroleum Institute. The "Most Likely" case projected by A.D. Little forecasts that diesel engines' share of the light truck market will grow to 24 percent by the 2015 model year. Diesel engines' share of the car market would grow somewhat more slowly, reaching 9 percent by 2015. The A.D. Little forecasts did not address the period after 2015; we have assumed that diesel sales stabilize at the level reached in 2015, with the fraction of in-use vehicles with diesel engines continuing to increase through turnover. We believe these projections are more realistic than the scenario of even higher sales of diesels described in the notice for the proposed Tier 2/Gasoline Sulfur program, though the A.D. Little forecasts still show much higher percentages of diesel vehicles in the light-duty fleet than have ever existed historically in the U.S.

The A.D. Little "most likely" scenario of increased diesels would result in dramatic increases in direct PM<sub>10</sub> emissions from cars and light trucks, if there were no change in these vehicles' PM standards. The increase in diesel exhaust PM<sub>10</sub> emissions would more than overcome the reduction in direct PM<sub>10</sub> attributable to the sulfur reduction in gasoline. With no change in the existing PM standards for cars and light trucks, our analysis of this scenario shows that direct PM<sub>10</sub> emissions in 2020 would be approximately 98,000 tons per year, which is nearly two times the 50,000 tons projected if diesel sales do not increase. The increase in diesel PM would be somewhat larger than the 48,000 ton difference between these two values, since the

difference also reflects the lower amount of PM from gasoline vehicles due to fewer gasoline vehicles in operation. The portion of ambient  $PM_{10}$  concentrations attributable to cars and light trucks would climb steadily.

The added  $PM_{10}$  emissions from cars and trucks due to an increase in diesel sales without action to reduce  $PM_{10}$  from each diesel vehicle would exacerbate the  $PM_{10}$  nonattainment problems of the areas listed in Tables III.C-6 and III.C-7, for which our air quality modeling predicted future nonattainment even without an increase in diesel sales. Moreover, it might cause  $PM_{10}$  nonattainment in the additional areas listed in Table III.C-8. Increases in  $PM_{10}$  emissions from more diesel vehicles would put these areas in greater risk of violating the  $PM_{10}$  NAAQS, especially if growth in other sources is high or meteorological conditions are more adverse than in the 1996 to 1998 period.

We have considered two approaches to quantifying the increased risk of  $PM_{10}$  nonattainment that could results from the additional PM emissions from more diesel cars and trucks. First, Section D of this chapter presents estimates of the population exposure to diesel PM that would result from higher diesel sales, with and without the more stringent PM emission standards. Table III.D-9 and the text preceding it indicate that increased sales of cars and light trucks without a more stringent PM emission standard could increase personal exposure to diesel PM by about  $0.2~\mu\text{g/m}^3$ . The exposure estimates in Section D estimates are based on an approach in which estimated personal exposures to carbon monoxide are adjusted based on ratios of emission inventories. They therefore incorporate the effect of personal movement among micro environments with more or less direct exposure to emissions and ambient air, and relate only indirectly to the monitored  $PM_{10}$  levels that determine attainment or nonattainment.

Our second approach to making a rough estimate of the possible contribution of diesel cars and light trucks to ambient  $PM_{10}$ , assuming the PM emission standard were not being made more stringent, was to first estimate the contribution of heavy-duty diesel vehicle PM to ambient  $PM_{10}$  for a historical period, and then adjust this by a PM emission inventory ratio of the quantity of diesel emissions associated with the historical contribution to ambient PM and the quantity that would be emitted from diesel cars and light trucks on a future date if sales of diesel cars and trucks did increase. The following paragraphs present an analysis along these lines.

The draft Health Assessment Document for Diesel Emissions includes a summary of the diesel PM findings of several source apportionment studies. The most commonly used receptor model for quantifying concentrations of diesel PM at a receptor site is the chemical mass balance model (CMB). Input to the CMB model includes PM measurements made at the receptor site as well as measurements made of each of the source types suspected to impact the site. Due to problems involving the elemental similarity between diesel and gasoline emission profiles and their co-emission in time and space, it is necessary to carefully quantify chemical molecular species which provide markers for separation of these sources (Lowenthal et al., 1992). Recent advances in chemical analytical techniques have facilitated the development of sophisticated

molecular source profiles including detailed speciation of organic compounds which allow the apportionment of PM to gasoline and diesel sources with increased certainty. Older studies which made use of only elemental source profiles have been published and are summarized here, but are subject to more uncertainty.

The CMB model has been used to assess the contribution of diesel PM to total PM mass in areas of California, Denver, CO, Phoenix, AZ, and Manhattan, NY (Table III.C-9). Diesel PM concentrations reported by Schauer et al. (1996) for data collected in 1982 ranged from 4.4  $\mu$ g/m³ in west Los Angeles to 11.6  $\mu$ g/m³ in Downtown Los Angeles. The average contribution of diesel PM to total PM mass ranged from 13 percent in Rubidoux to 36 percent in downtown Los Angeles. It should be noted that this model accounts for primary emissions of diesel PM only and the contribution of secondary aerosol formation (both acid and organic aerosols) is not included. In sites downwind from urban areas, such as Rubidoux in this study, secondary nitrate formation can account for a substantial fraction of the mass (25 percent of the fine mass measured in Rubidoux was attributed to secondary nitrate), a portion of which comes from diesel exhaust.<sup>30</sup>

Table III.C-9. Ambient Diesel PM Concentrations Reported from Chemical Mass Balance Modeling

Author	Year of Sampling, No. days	Location	Location Type	Source Profile Used	Total PM2.5 (stdev), µg/m³	Diesel PM2.5 (stdev), µg/m³
Schauer et al., 1996 Southern California	1982, 60 days (one every sixth day)	West LA Pasadena Rubidoux Downtown LA	Urban Urban Suburban Urban	OC Species, EC, Elements	24.5 (2.0) 28.2 (1.9) 42.1 (3.3) 32.5 (2.8)	4.4 (0.6) 5.3 (0.7) 5.4 (0.5) 11.6 (1.2)
Chow et al., 1991	Winter, 1989- 90 †	Phoenix, AZ Area	Urban	†	†	4-22*
California EPA, 1998	1988-92, approx. 150 days	15 Air Basins	Rural-Urban	EC, OC total, Elements, Major Ions	†	0.2-3.6*
Wittorff, 1994	Spring, 1993, 3 days	Manhattan, NY	Urban Bus Stop	EC, OC total, Elements, Major Ions	35.8-83.0	13.2-46.7*
NFRAQS, 1998	Winter, 1996- 97, 60 days	Welby, CO Brighton, CO	Urban Suburban	OC Species, EC, Elements, Major ions	16.7 12.4	1.7 1.2

\*PM10

† Not available

OC: Organic Carbon EC: Elemental Carbon

Major Ions: nitrate, sulfate, chloride and in some cases ammonium, sodium, potassium

A wintertime study conducted in the Phoenix, AZ area by Chow et al.,  $^{31}$  indicated that diesel PM levels on single days can range from 4  $\mu g/m^3$  in west, and central Phoenix, to 14  $\mu g/m^3$  in south Scottsdale and 22  $\mu g/m^3$  in central Phoenix. This apportionment, like the Schauer et al., (1996) data, reflects direct emissions only. These data relied on source profiles and ambient data collected prior to the introduction of technology to reduce PM emissions from diesel-powered vehicles. This study has not appeared in the peer reviewed literature.

A second CMB study reported ambient diesel PM concentrations for California and used ambient measurements from the San Joaquin Valley (1988-89), South Coast (1986), and San Jose (winters for 1991-92 and 1992-93). The incorporation of sampling data from later dates provides information regarding exposures more relevant to current levels. The CMB in the California study (1998a) indicated that on an annual basis, basin-wide levels of direct diesel PM emissions may be as low as  $0.2 \,\mu\text{g/m}^3$  in the Great Basin Valleys and as high as  $3.6 \,\mu\text{g/m}^3$  in the South Coast basin.

The most recent study reporting diesel PM concentrations is from winter 1996-1997 sampling conducted in the Denver, CO area as part of the Northern Front Range Air Quality Study (NFRAQS, 1998). Ambient levels of diesel PM in the urban core site at Welby averaged  $1.7~\mu g/m^3$  over a 60-day winter period and a slightly lower average concentration of  $1.2~\mu g/m^3$  was measured at an urban downwind site in Brighton, CO. One of the major findings from this study was a substantial contribution of elemental carbon from gasoline-powered vehicles. At the Welby site, the contribution of diesel and gasoline emissions to elemental carbon measurements was 52 percent and 42 percent, respectively. At the Brighton site, the contribution of diesel and gasoline emissions to elemental carbon measurements was 71 percent and 26 percent, respectively. The findings from the NFRAQS study are compelling and suggest the need for further investigations of this type that specifically address high-emitting vehicles. Geographical and other site-specific parameters that influence PM concentrations, such as altitude, must be considered when extrapolating the NFRAQS findings to other locations

Limited data are available which allow a characterization of diesel PM concentrations in 'hot spots' such as near heavily traveled roadways, bus stations, train stations, and marinas. One 'hotspot' study conducted in Manhattan, NY reported diesel PM concentrations of 13.0 to 46.7  $\mu g/m^3$  during a three-day sampling period in the spring of 1993 (Wittorff,1994). This study attributed, on average, 50 percent of the PM to diesel exhaust. The diesel PM concentrations resulting from the source apportionment method used in this study require some caution. The CMB model overpredicted PM10 concentrations by an average 30 percent, suggesting that additional sources of the mass were not accounted for in the model. New advances in organic carbon speciation, as has been noted above, are necessary to most appropriately characterize gasoline and diesel PM sources to ambient PM measurements. The relevance of the Manhattan bus stop exposure for large urban populations provides strong motivation for further studies in the vicinity of such 'hotspots'. This study has not appeared in the peer reviewed literature.

In summary, recent source apportionment studies (California EPA, 1998; NFRAQS, 1998) indicate that ambient diesel PM concentrations averaged over 2-12 month periods for urban/suburban areas can range from approximately  $1.2~\mu g/m^3$  to  $3.6~\mu g/m^3$ , while diesel PM concentrations in more rural/remote areas are generally less than  $1.0~\mu g/m^3$ . In the vicinity of 'hot spots', or for short exposure times under episode-type conditions diesel PM concentrations are expected to be substantially higher than these levels, as high as 22 and 47  $\mu g/m^3$ . However, a thorough and replicated characterization of these situations is not yet available. Two studies nearing completion by the South Coast Air Quality Management District will shed some light on near-highway concentrations of diesel PM. <sup>33</sup>

To quantify the potential contribution that diesel cars and light trucks may make to ambient PM10 concentrations, we have used the four numbers cited in the previous paragraph (1.2, 3.6, 22, and 47  $\mu g/m^3$ ) as starting points, recognizing that the latter two values have considerable uncertainty for reasons explained above. We assume that these estimated ambient concentrations are attributable to highway diesel vehicles, and specifically to heavy-duty vehicles because of the near-zero use of diesel engines in other classes in the time frames of these studies.<sup>21</sup>

Table III.C-10 summarizes this analysis, combining key findings from the studies just summaried with emissions estimates from the Tier 2 analysis, to predict increases in PM10 in 2030. A needed detail from the 47-state inventories described in Section A of this chapter is that 47-state PM emissions from all diesel vehicles in 1996 (the year of NFRAQS) was 160,109 tons. This figure must be adjusted to the time frame for each of the other three estimates of ambient diesel PM concentration. We have done this using the emissions trends given in the 1997 Emission Trends report, applying the ratio of two calendar year's 50-state emissions to the 47-state estimate for 1996.<sup>34</sup> The 2030 PM emissions from diesel cars and light trucks under the scenario of higher diesel car and light truck sales without more stringent PM emission standards would be 77,421 tons.

The final columns of Table III.C-10 suggest that with higher sales of diesel cars and light trucks, they could contribute between 0.6 to  $20~\mu g/m^3$  to  $PM_{10}$  concentrations. This would represent between one-half and 40 percent of the  $PM_{10}$  concentration allowed by the NAAQS, with the upper end of this range based on studies conducted in roadside situations with heavy traffic and using older and more simple approaches to source apportionment.

<sup>&</sup>lt;sup>21</sup> Non-road diesel engines also operate in urban areas, and may actually have contributed somewhat to the ambient concentrations observed in the various studies. To the extent that they did, the estimates of the possible future contribution to ambient PM from diesel cars and light trucks would be overestimates.

# **Chapter III: Environmental Impact**

Table III.C-10. Estimation of Potential Contribution of Diesel Cars and Light Trucks to Ambient PM<sub>10</sub> Concentrations in 2030

Study Used as Starting Point	Ambient PM10 from Diesels in Study µg/m³	Assumed Year of Study	Highway Heavy-Duty Diesel PM10 Emissions at Time of Study (47-state annual tons) *	2030 Light-Duty Diesel PM10 Emissions (47-state annual tons)**	Estimate of 2030 Ambient PM10 from Light-Duty Diesels (µg/m³)***	Percentage of 24-hour PM10 NAAQS	Percentage of Annual PM10 NAAQS
NFRAQS, 1998	1.2	1996	160,109	77,421	0.6	0.4 %	1.2 %
California EPA, 1998	3.6	1990	213,479	77,421	1.3	0.9 %	1.8 %
Chow et al., 1991	22	1990	213,479	77,421	8.0	5.3 %	16.0 %
Wittorff, 1994	47	1993	181,175	77,421	20.1	13.4 %	40.2 %

<sup>\*</sup> Interpolated from EPA Emissions Trends Report.

\*\* Derived from estimates in Section A of this chapter.

\*\*\* Concentration estimate from study multiplied by ratio of emissions estimates.

The standards included in today's actions will result in a steady decrease in total direct  $PM_{10}$  from cars and light trucks even if this increase in the use of diesel engines in these vehicles were to occur. If the A.D. Little scenario for increased diesel engines in light trucks were to occur, today's actions would reduce diesel  $PM_{10}$  from cars and light trucks by over 75 percent in 2020. Stated differently, by 2030 today's actions would reduce over 93,000 tons of the potential increase in  $PM_{10}$  emissions from passenger cars and light trucks. The result would be less direct  $PM_{10}$  than is emitted today, because the increase in diesel  $PM_{10}$  would be more than offset by the reduction in gasoline  $PM_{10}$ .

It should be noted that the analysis of the economic benefits of the Tier 2/Gasoline Sulfur program does not include any effects related to the possible increase in sales of diesel cars and light trucks or the to the control of the PM increase that would otherwise occur if the PM standard were not being revised.

Fortunately, the standards included in today's actions will result in a steady decrease in total direct  $PM_{10}$  from cars and light trucks even if this increase in the use of diesel engines in these vehicles were to occur. If the A.D. Little scenario for increased diesel engines in light trucks were to occur, today's actions would reduce diesel  $PM_{10}$  from cars and light trucks by over 75 percent in 2020. Stated differently, by 2030 today's actions would reduce over 93,000 tons of the potential increase in  $PM_{10}$  emissions from passenger cars and light trucks. The result would be less direct  $PM_{10}$  than is emitted today, because the increase in diesel  $PM_{10}$  would be more than offset by the reduction in gasoline  $PM_{10}$ .

We are establishing tighter PM standards for diesel vehicles because of the impact greater diesel PM emissions would have on PM<sub>10</sub> attainment and public health and welfare if diesel sales increased in the future without the protection of the tighter standards. Because diesel vehicles will essentially be performing the same functions as the gasoline vehicles they will replace, it is appropriate for the new PM standards to also apply equally to gasoline and diesel vehicles. We expect that gasoline vehicles will need little or no redesign to meet the new PM standards when free of defects and properly operating. However, the new standards may achieve some reduction in real world PM emissions from gasoline vehicles by encouraging more durable designs. The new standards for PM will also prevent any changes in gasoline engine design which would increase PM emissions. These changes would otherwise be possible because of the current PM standard is so much higher than the current performance on the gasoline vehicles.

#### f. Reductions In Ambient PM

In general, we project that the Tier 2/Gasoline Sulfur program will reduce both direct and secondary PM from cars and light trucks substantially, regardless of the future market share for diesel engines in the light-duty fleet. The larger part of the reduction is due to large reductions in VOC, NOx, and SOx emissions, with corresponding reductions in secondary PM formation.

Low sulfur fuel will greatly reduce direct PM emissions and sulfate-based secondary PM formation from SOx emissions from gasoline vehicles, while tailpipe PM standards are projected to mitigate excess PM emissions from diesel vehicles, even at very aggressive rates of diesel vehicle sales growth. Substantial reductions in NOx emissions will carry over to reductions in indirect PM. These reductions will help reduce the number of areas with PM<sub>10</sub> and PM<sub>2.5</sub> levels in excess of national standards, reduce the severity of PM nonattainment in other areas, and help areas facing PM maintenance challenges stay in attainment.

The magnitude of the PM reductions from today's actions in a given area depends on conditions such as the contribution of light-duty vehicles to the local PM, SOx, NOx, and VOC inventory; the contribution of light-duty vehicles to the PM, SOx, NOx, and VOC inventories in upwind areas; local and upwind ammonia inventories (involved in secondary PM formation); control measures being implemented on both local and upwind sources of PM and its precursors, and local meteorology. We have incorporated these factors into the air quality modeling used to develop the benefit/cost analysis presented in Chapter VII, which includes the economic benefits of the direct and secondary PM reductions expected to result from today's actions. The estimates of annual average ambient PM<sub>2.5</sub> reductions with full program implementation and phase-in in 2030 are presented in a contractor report that was part of the benefit/cost analysis. Reductions are given as an average for each state, and in the form of a shaded map. Reductions are larger in urban areas than rural, and larger in the east than in the sparsely populated areas of the west. The PM<sub>2.5</sub> reductions and PM<sub>10</sub> reductions are essentially equal. State-wide average ambient PM reductions range from 0.04  $\mu$ g/m<sup>3</sup> in Nevada, reflecting its large areas with low vehicle travel, to  $0.45 \mu g/m^3$  in Washington, DC. Much of the eastern half of the U.S. is estimated to have a reduction of at least 0.20  $\mu$ g/m<sup>3</sup>, with the largest reduction in any county being 1.25  $\mu$ g/m<sup>3</sup>.

## 2. Visibility/Regional Haze

Visibility is greatly affected by ambient  $PM_{2.5}$  concentration, with  $PM_{2.5}$  concentrations below the NAAQS being sufficient to impair visibility. The reductions in ambient  $PM_{2.5}$  from the Tier 2/Gasoline Sulfur program will contribute to visibility improvements across the U.S. The geographical pattern of the improvement mirrors that of the  $PM_{2.5}$  reductions. Visibility improvements have value to Americans in both recreational areas traditionally known for scenic vistas, and in the urban areas where people spend most of their time.

The Grand Canyon Visibility Transport Commission examined visibility impairment on the Colorado Plateau. Figures II-4 and II-5 in the Commission's contain estimates for the contribution of 11 different sources to the man-made visibility impairment at Hopi Point<sup>35</sup>. Figure II-4 is for annual average light extinction<sup>22</sup> and Figure II-5 for the worst days. Each

<sup>&</sup>lt;sup>22</sup> Light extinction is a measure of visibility impairment.

figure gives estimates for 1990, 2000, 2010, and 2040. In 2000, for both annual average and worst days, the contribution from "Mobile" to light extinction is about 10 percent. EPA understands this category to consist of highway vehicles only, since there is a separate category for "Non Road Diesel." Furthermore, the "Mobile" category must exclude dust caused by highway vehicle travel since there is a separate category for "Road Dust." The road dust category is estimated to be responsible for about 30 percent of light extinction at Hopi Point.

It is generally recognized that the traditionally-used emission factors and transport assumptions for road dust have considerable uncertainty. Emissions inventory estimates generally suggest a greater role for road dust than is suggested by studies of ambient PM. This discrepancy is thought to result from the generally shorter atmospheric residence time for road dust due to its greater size and lack of inherent thermal buoyancy, as well as its greater filtration by vegetation, than other sources of PM. Therefore, the contribution of road dust may be overstated in the estimates described in the preceding paragraph. If light extinction from highway vehicles is expressed as a percentage of all light extinction not attributable to road dust, the highway vehicle contribution is 14 percent. Hence the reductions in highway vehicle emissions from the Tier 2/Gasoline Sulfur program can contribute significantly to improved visibility on the Colorado Plateau.

The economic benefits analysis reported in Chapter VII included modeling to determine the degree of visibility improvement, and estimated the economic value of visibility improvements in both recreational and residential settings.

#### D. Air Toxics

This section summarizes our analysis of the impact of the final Tier 2 standards on emissions of and exposure to air toxics. Section D.1 reviews the effects of selected air toxics emissions on human health. Section D.2 describes our analysis of air toxics emissions and exposure and the effect that the proposed Diesel Sulfur standards may have on air toxics emissions and exposure.

#### 1. Health Effects

Our assessment of motor vehicle toxics focused on the following compounds with cancer potency estimates that have or could have significant emissions from light-duty as well as heavy-duty vehicles: benzene, 1,3-butadiene, formaldehyde, acetaldehyde, and diesel PM. It should be noted, however, that the EPA does not have an official quantitative estimate of diesel emissions potency at present. A brief summary of health effects information on these compounds follows. The information in this section is based on our preliminary study of motor vehicle toxics emissions. The methodology used to develop these estimates has recently undergone peer review.

#### a. Benzene

Benzene is an aromatic hydrocarbon which is present as a gas in both exhaust and evaporative emissions from motor vehicles. Benzene in the exhaust, expressed as a percentage of total organic gases (TOG), varies depending on control technology (e.g., type of catalyst) and the levels of benzene and aromatics in the fuel, but is generally about three to five percent. The benzene fraction of evaporative emissions depends on control technology (i.e., fuel injector or carburetor) and fuel composition (e.g., benzene level and Reid Vapor Pressure, or RVP) and is generally about one percent.

The EPA has recently reconfirmed that benzene is a known human carcinogen by all routes of exposure. At least half of this exposure is by way of gasoline vapors and automotive emissions (EPA 1998a). Long-term exposure to high levels of benzene in air has been shown to cause cancer of the tissues that form white blood cells. Among these are acute nonlymphocytic<sup>23</sup> leukemia, chronic lymphocytic leukemia and possibly multiple myeloma (primary malignant tumors in the bone marrow), although the evidence for the latter has decreased with more recent studies.<sup>37,38</sup> Leukemias, lymphomas, and other tumor types have been observed in experimental animals that have been exposed to benzene by inhalation or oral administration (EPA 1985, Clement 1991). Exposure to benzene and/or its metabolites has also been linked with genetic changes in humans and animals<sup>39</sup> and increased proliferation of mouse bone marrow cells<sup>40</sup>. Furthermore, the occurrence of certain chromosomal changes in individuals with known exposure to benzene may serve as a marker for those at risk for contracting leukemia.<sup>41</sup>

The latest assessment by EPA places the excess risk of developing acute nonlymphocytic leukemia at  $2.2 \times 10^{-6}$  to  $7.7 \times 10^{-6}/\mu g/m^3$  (EPA, 1998a). In other words, there is a risk of two to eight excess acute nonlymphocytic leukemia cases in one million people exposed to  $1\mu g/m^3$  benzene over a lifetime (70 years). These numbers represent the maximum likelihood (MLE) estimate of risk, not an upper confidence limit (UCL).

Leukemia is a blood disease in which the white blood cells are abnormal in type or number. Leukemia may be divided into nonlymphocytic (granulocytic) leukemias and lymphocytic leukemias. Nonlymphocytic leukemia generally involves the types of white blood cells (leukocytes) that are involved in engulfing, killing, and digesting bacteria and other parasites (phagocytosis) as well as releasing chemicals involved in allergic and immune responses. This type of leukemia may also involve erythroblastic cell types (immature red blood cells). Lymphocytic leukemia involves the lymphocyte type of white bloods cell that are responsible for the immune responses. Both nonlymphocytic and lymphocytic leukemia may, in turn, be separated into acute (rapid and fatal) and chronic (lingering, lasting) forms. For example; in acute myeloid leukemia (AML) there is diminished production of normal red blood cells (erythrocytes), granulocytes, and platelets (control clotting) which leads to death by anemia, infection, or hemorrhage. These events can be rapid. In chronic myeloid leukemia (CML) the leukemic cells retain the ability to differentiate (i.e., be responsive to stimulatory factors) and perform function; later there is a loss of the ability to respond.

A number of adverse noncancer health effects, blood disorders such as preleukemia and aplastic anemia, have also been associated with low-dose, long-term exposure to benzene (EPA 1985, Clement 1991, 42). People with long-term exposure to benzene may experience harmful effects on the blood-forming tissues, especially the bone marrow. These effects can disrupt normal blood production and cause a decrease in important blood components, such as red blood cells and blood platelets, leading to anemia (a reduction in the number of red blood cells), leukopenia (a reduction in the number of white blood cells), or thrombocytopenia (a reduction in the number of blood platelets, thus reducing the ability for blood to clot). Chronic inhalation exposure to benzene in humans and animals results in pancytopenia<sup>24</sup>, a condition characterized by decreased numbers of circulating erythrocytes (red blood cells), leukocytes (white blood cells), and thrombocytes (blood platelets). 43,44 Individuals that develop pancytopenia and have continued exposure to benzene may develop aplastic anemia, 25 whereas others exhibit both pancytopenia and bone marrow hyperplasia (excessive cell formation), a condition that may indicate a preleukemic state. 45,46The most sensitive noncancer effect observed in humans is the depression of absolute lymphocyte counts in the circulating blood<sup>47</sup>. A draft reference concentration (RfC) has been developed for benzene. The reference concentration (RfC) is an estimate of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious noncancer effects during a lifetime; these estimates frequently have uncertainty levels that span perhaps an order of magnitude. The draft benzene RfC is 9 µg/m<sup>3</sup>, which means that long-term exposures to benzene should be kept below 9 µg/m<sup>3</sup> to avoid appreciable risks of these non-cancer effects.<sup>48</sup> This RfC is currently being revised.

#### b. 1.3-Butadiene

1,3-Butadiene is formed in vehicle exhaust by the incomplete combustion of the fuel. It is not present in vehicle evaporative and refueling emissions, because it is not present in any appreciable amount in gasoline. 1,3-Butadiene accounts for 0.4 to 1.0 percent of total exhaust TOG, depending on control technology and fuel composition.

1-3-Butadiene was classified by EPA as a Group B2 (probable human) carcinogen in

<sup>&</sup>lt;sup>24</sup> Pancytopenia is the reduction in the number of all three major types of blood cells (erythrocytes, or red blood cells, thrombocytes, or platelets, and leukocytes, or white blood cells). In adults, all three major types of blood cells are produced in the bone marrow of the vertebra, sternum, ribs, and pelvis. The bone marrow contains immature cells, known as multipotent myeloid stem cells, that later differentiate into the various mature blood cells. Pancytopenia results from a reduction in the ability of the red bone marrow to produce adequate numbers of these mature blood cells.

Aplastic anemia is a more severe blood disease and occurs when the bone marrow ceases to function, i.e.,these stem cells never reach maturity. The depression in bone marrow function occurs in two stages - hyperplasia, orincreased synthesis of blood cell elements, followed by hypoplasia, or decreased synthesis. As the disease progresses, thebone marrow decreases functioning. This myeloplastic dysplasia (formation of abnormal tissue) without acute leukemiais known as preleukemia. The aplastic anemia can progress to AML (acute mylogenous leukemia).

1985.<sup>49</sup> This classification was based on evidence from two species of rodents and \*\*\* epidemiologic data. EPA recently prepared a draft assessment that would determine sufficient evidence exists to propose that 1,3-butadiene be classified as a known human carcinogen.<sup>50</sup> However, the Environmental Health Committee of EPA's Scientific Advisory Board (SAB), in reviewing the draft document, issued a majority opinion that 1,3-butadiene should instead be classified as a probable human carcinogen.<sup>51</sup> In the draft EPA assessment, the MLE estimate of a lifetime extra cancer risk from continuous 1,3-butadiene exposure is about  $3.9 \times 10^{-6}/\mu g/m^3$ . In other words, it is estimated that approximately 4 persons in one million exposed to 1 µg/m<sup>3</sup> 1,3butadiene continuously for their lifetime (85 years in this case) would develop cancer as a result of their exposure. Lower

exposures are expected to result in risks that are lower.

The unit risk estimates presented in EPA's draft risk assessment were not accepted by the SAB. The SAB panel recommended that EPA recalculate the lifetime cancer risk estimates based on the human data from Delzell et al. 1995<sup>52</sup> and revise EPA's original calculations to account for the highest exposure of "360 ppm-year" instead of "250+ ppm-year" and 70 years at risk instead of 85 years. Based on these recalculations<sup>53</sup> the MLE estimate of lifetime cancer risk from continuous 1,3-butadiene exposure is  $2.21 \times 10^{-6} / \mu g/m^3$ . This estimate implies that approximately 2 persons in one million exposed to 1 µg/m<sup>3</sup> 1,3-butadiene continuously for their lifetime (70 years in this case) would develop cancer as a result of their exposure.

1,3-Butadiene also causes a variety of reproductive and developmental effects in mice and rats (no human data) when exposed to long-term, low doses of butadiene (EPA 1998c). The most sensitive effect was reduced litter size at birth and at weaning. These effects were observed in studies in which male mice exposed to 1,3-butadiene were mated with unexposed females. In humans, such an effect might manifest itself as an increased risk of spontaneous abortions, miscarriages, still births, or very early deaths. Long-term exposures to 1,3-butadiene should be kept below its reference concentration of 0.33 µg/m<sup>3</sup> to avoid appreciable risks of these reproductive and developmental effects (EPA 1998c).

#### **Formaldehyde** c.

Formaldehyde is the most prevalent aldehyde in vehicle exhaust. It is formed from incomplete combustion of both gasoline and diesel fuel and accounts for one to four percent of total exhaust TOG emissions, depending on control technology and fuel composition. It is not found in evaporative emissions.

Formaldehyde exhibits extremely complex atmospheric behavior.<sup>54</sup> It is present in emissions and is also formed by the atmospheric oxidation of virtually all organic species, including biogenic (produced by a living organism) hydrocarbons. Mobile sources contribute both primary formaldehyde (emitted directly from motor vehicles) and secondary formaldehyde (formed from photooxidation of other VOCs emitted from vehicles). The mobile source

contribution is difficult to quantify, but it appears that at least 30 percent of formaldehyde in the ambient air may be attributable to motor vehicles (EPA 1993a).

EPA has classified formaldehyde as a probable human carcinogen<sup>55</sup> based on limited evidence for carcinogenicity in humans and sufficient evidence of carcinogenicity in animal studies, rats, mice, hamsters, and monkeys. Epidemiological studies in occupationally exposed workers suggest that long-term inhalation of formaldehyde may be associated with tumors of the nasopharyngeal cavity (generally the area at the back of the mouth near the nose), nasal cavity, and sinus (Clement 1991, EPA 1993a). Studies in experimental animals provide sufficient evidence that long-term inhalation exposure to formaldehyde causes an increase in the incidence of squamous (epithelial) cell carcinomas (tumors) of the nasal cavity (Clement 1991, EPA 1993a, EPA 1987). The distribution of nasal tumors in rats suggests that not only regional exposure but also local tissue susceptibility may be important for the distribution of formaldehyde-induced tumors (Clement 1991, EPA 1993a). Research has demonstrated that formaldehyde produces mutagenic activity in cell cultures.

The MLE estimate of a lifetime extra cancer risk from continuous formaldehyde exposure is about  $1.3 \times 10^{-6}/\mu g/m^3$ . In other words, it is estimated that approximately 1 person in one million exposed to 1  $\mu g/m^3$  formaldehyde continuously for their lifetime (70 years) would develop cancer as a result of this exposure. Lower exposures are expected to result in risks that are lower.

Formaldehyde exposure also causes a range of noncancer health effects. At low concentrations (0.05-2.0 ppm), irritation of the eyes (tearing of the eyes and increased blinking) and mucous membranes is the principal effect observed in humans. At exposure to 1-11 ppm, other human upper respiratory effects associated with acute formaldehyde exposure include a dry or sore throat, and a tingling sensation of the nose. Sensitive individuals may experience these effects at lower concentrations. Forty percent of formaldehyde-producing factory workers reported nasal symptoms such as rhinitis (inflammation of the nasal membrane), nasal obstruction, and nasal discharge following chronic exposure. In persons with bronchial asthma, the upper respiratory irritation caused by formaldehyde can precipitate an acute asthmatic attack, sometimes at concentrations below 5 ppm; I formaldehyde exposure may also cause bronchial asthma-like symptoms in nonasthmatics. However, it is unclear whether asthmatics are more sensitive than nonasthmatics to formaldehyde's effects.

Immune stimulation may occur following formaldehyde exposure, although conclusive evidence is not available. Also, little is known about formaldehyde's effect on the central nervous system. Several animal inhalation studies have been conducted to assess the developmental toxicity of formaldehyde: The only exposure-related effect noted was decreased maternal body weight gain at the high-exposure level but no adverse effects on reproductive outcome of the fetuses that could be attributed to treatment were noted. An inhalation reference concentration (RfC), below which long-term exposures would not pose appreciable non-cancer

health risks, is not available for formaldehyde at this time.

## d. Acetaldehyde

Acetaldehyde is a saturated aldehyde that is found in vehicle exhaust and is formed as a result of incomplete combustion of both gasoline and diesel fuel. It is not a component of evaporative emissions. Acetaldehyde comprises 0.4 to 1.0 percent of exhaust TOG, depending on control technology and fuel composition.

The atmospheric chemistry of acetaldehyde is similar in many respects to that of formaldehyde (Ligocki et al., 1991,  $^{61}$ ). Like formaldehyde, it can be both produced and destroyed by atmospheric chemical transformation, so mobile sources contribute to ambient acetaldehyde levels both by their primary emissions and by secondary formation resulting from their VOC emissions. Data from emission inventories and atmospheric modeling indicate that roughly 40 percent of the acetaldehyde in ambient air may be attributable to mobile sources. Acetaldehyde emissions are classified as a probable human carcinogen. The MLE estimate of a lifetime extra cancer risk from continuous acetaldehyde exposure is about  $0.78\times 10^{-6}\,/\mu g/m^3$ . In other words, it is estimated that less than 1 person in one million exposed to  $1\,\mu g/m^3$  acetaldehyde continuously for their lifetime (70 years) would develop cancer as a result of their exposure.

Non-cancer effects in studies with rats and mice showed acetaldehyde to be moderately toxic by the inhalation, oral, and intravenous routes.  $^{62, 63, 64}$  The primary acute effect of exposure to acetaldehyde vapors is irritation of the eyes, skin, and respiratory tract. At high concentrations, irritation and pulmonary effects can occur, which could facilitate the uptake of other contaminants. Little research exists that addresses the effects of inhalation of acetaldehyde on reproductive and developmental effects. The *in vitro* and *in vivo* studies provide evidence to suggest that acetaldehyde may be the causative factor in birth defects observed in fetal alcohol syndrome, though evidence is very limited linking these effects to inhalation exposure Long-term exposures should be kept below the reference concentration of 9  $\mu$ g/m³ to avoid appreciable risk of these non-cancer health effects.  $^{65}$ 

#### e. Diesel Particulate Matter

Diesel exhaust includes components in the gas and particle phases. The diameter of diesel particles is very small with typically 75-95 percent of the particle mass having a diameter smaller than 1.0 µm. The characteristically small particle size increases the likelihood that the particles and the attached compounds will reach and lodge in the deepest areas of the human lung. Gaseous components of diesel exhaust include nitrates, sulfur compounds, organic compounds, carbon monoxide, carbon dioxide, water vapor, and excess air (nitrogen and oxygen). Among these gas-phase constituents, the components suspected to have carcinogenic potential are the organic compounds (including benzene, formaldehyde, acetaldehyde, 1,3-

butadiene). Current studies have not been designed to specifically discern a role for the gaseous compounds in contributing to diesel exhaust carcinogenicity, but it is likely that some portion can be attributed to gas phase organics.

While some of the cancer risk is likely associated with exposure to the gaseous components of diesel exhaust, studies conducted suggest that the particulate component plays a substantial role in carcinogenicity. Information that is currently available suggests that the particulate fraction of diesel exhaust is carcinogenic independent of the gaseous component. Specifically, (1) diesel particles (the elemental carbon core plus the adsorbed organics) induce lung cancer at high doses, and the particles, independent of the gaseous compounds, elicit an animal lung cancer response; (2) the presence of elemental carbon particles as well as the organic-laden diesel particles correlate with an adverse inflammatory effect in the respiratory system of animals, with some limited evidence in humans; (3) the extractible particle organics taken collectively produce cancer and adverse mutagenic toxicity in experimental test systems; and (4) many of the individual organic compounds adsorbed onto the particles are mutagenic or carcinogenic in their own right (EPA, 1999b). This information suggests that the particle may be playing a dual role in contributing to the carcinogenicity of diesel exhaust: both as a mechanism of delivery for many of the organics into the respiratory system, and the role of the elemental carbon core.

In two human studies on railroad workers and one on Teamster Union Truck Drivers and attendant personnel who were occupationally exposed to diesel exhaust (EPA 1999b), it was observed that long-term inhalation of diesel exhaust produced an excess risk of lung cancer. Taken together, these and other human studies show a positive association between diesel exhaust exposure and lung cancer. While some uncertainties remain about confounding from smoking and possible coincident exposures to other agents, the totality of human evidence provides a strong inference for a human lung cancer hazard. Inhalation studies in rats show a lung cancer response at high doses, though the rat model is not deemed a satisfactory test system for indicating a low exposure hazard for humans. Results from inhalation studies in mice range from equivocal to suggestive but are not compelling (EPA 1999b). Lung implantation animal studies do show the carcinogenic reactivity of diesel particulates and the extracted organics. Extensive mutagenicity and genotoxicity studies show that the particle organics and the gaseous fractions are reactive and it is also evident that a number of the organic constituents present on the particles and in the gases are carcinogenic in their own right, though not necessarily in the lung (EPA 1999b). EPA's draft Diesel Health Assessment also identifies several types of adverse chronic respiratory effects including respiratory tract irritation/inflammation, changes in lung function, and a suggestion of adverse immunological changes as concerns for long term exposure to diesel exhaust. The evidence for chronic respiratory effects comes mainly from animal studies (the rat being the most studied), given the limited availability of human studies. The evidence for both cancer and chronic respiratory effects comes from the studies involving occupational exposures and or high exposure animal studies. The Agency's draft assessment (EPA, 1999b) stated that diesel exhaust is a highly likely human lung cancer hazard, but that the

data are currently unsuitable to make a confident quantitative statement of risk. The draft assessment also states that this risk is applicable to ambient exposures and that the risk may be in the range of regulatory interest (greater than one in a million over a lifetime). In addition, EPA believes that keeping long term exposures to diesel particulate matter at or below  $5 \,\mu\text{g/m}^3$  provides an adequate margin of safety for the noncancer chronic respiratory hazards.

The California Air Resources Board has identified diesel exhaust PM as a "toxic air contaminant" under the state's air toxics program, based on the information available on cancer and non-cancer health effects. California is in the process of determining the need for, and appropriate degree of, control measures for diesel exhaust particulate matter. Note that California limited its finding to diesel particulate matter, as opposed to diesel exhaust. EPA's assessment activities of diesel exhaust PM are coincident with, but independent from, ARB's evaluation. Based on human epidemiology studies, the ARB's estimate of the range of a lifetime upper confidence limit unit cancer risk from continuous diesel exhaust particulate exposure ranges from  $1.3 \times 10^{-4}$  to  $2.4 \times 10^{-3}~\mu\text{g/m}^3$  (lifetime-  $\mu\text{g/m}^3$ )-1. The geometric mean unit risk obtained from these end points of the range is  $6 \times 10^{-4}$  (lifetime-  $\mu\text{g/m}^3$ )-1. In other words, it is estimated that approximately 130 to 2400 persons in one million Californians exposed to  $1~\mu\text{g/m}^3$  diesel exhaust particulate continuously for their lifetime (70 years) would develop cancer as a result of their exposure.

Particulates (i.e, particulate matter, PM) are a prominent part of diesel exhaust and play a role in contributing to total ambient PM, especially PM<sub>2.5</sub> (PM less than 2.5 µm in diameter). This means that EPA's new National Ambient Air Quality Standard for PM<sub>2.5</sub> provides another health-based reference point, though the health concerns from exposure ambient PM vs diesel have differences as well as similarities. As diesel particulates make up more and more of the ambient PM mixture, the health concerns would overlap to a larger extent. Compared to a typical ambient PM mixture from many sources, diesel exhaust particles probably have a higher percentage of small particles which also have a higher surface area laden with adsorbed organics.

## 2. Assessment of Emissions and Exposure

In 1993, EPA released the "Motor Vehicle-Related Air Toxics Study" to meet the requirements of Section 202(l)(1) of the Clean Air Act, which required EPA to complete a study of the need for, and feasibility of, controlling emissions of toxic air pollutants associated with motor vehicles and motor vehicle fuels (EPA 1993a). In 1998, EPA updated the emissions and exposure analyses done for this study to account for new information<sup>67,68</sup> Base scenarios for 1990, 1996, 2007, and 2020 were included in the assessment, as well as several control scenarios in 2007 and 2020. Toxic emissions and exposure were modeled for nine urban areas and the results were extrapolated nationwide. Results from these analyses were summarized in the draft regulatory impact analysis for the proposal for this rulemaking. These analyses have been updated and extended for the final rule.<sup>69</sup> First, additional areas were modeled to encompass a

broader selection of I/M programs, fuel parameters, and temperature regimes. This enabled us to develop more accurate nationwide extrapolations. Second, model inputs were revised to reflect more recent information on emission rates, and to reflect the standards being promulgated in the final rule. As mentioned previously, EPA has assessed emissions and exposure from the following air toxics: benzene, formaldehyde, acetaldehyde, 1,3-butadiene, and diesel particulate matter. An assessment of the cancer and non-cancer effects of mobile source emissions of these compounds has not yet been completed as part of the updated analyses.

This subsection describes the analysis we have conducted for the final rule. Subsection D.2.a. discusses the emission modeling conducted for mobile source gaseous air toxics (including both exhaust and nonexhaust air toxics) and diesel PM. Subsection D.2.b. describes how we calculated nationwide air toxic emissions for our baseline scenario, which assumed continuation of the National Low Emission Vehicle program indefinitely. Subsection D.2.c. describes our analysis of air toxics exposure for our baseline scenario. Subsection D.2.d. describes our analysis of the effects of various vehicle and fuel control scenarios on air toxics emissions and exposure. It also describes how we used those analyses to estimate the effect of the proposed Tier 2/Sulfur standards on air toxics emissions. This subsection also reviews our analysis of the potential impact of increased diesel engine use in cars and light trucks on diesel PM emissions and exposure.

## a. Emissions Modeling

# i. Gaseous Air Toxics Emissions Modeling

In these analyses, emissions of benzene, formaldehyde, acetaldehyde, and 1,3-butadiene were estimated using a toxic emission factor model, MOBTOX5b. This model is based on a modified version of MOBILE5b, which estimates emissions of regulated pollutants, and essentially applies toxic fractions to total organic gas (TOG) estimates. The TOG basic emission rates used in this modeling incorporated the available elements for MOBILE6 used to develop the VOC inventory for this rule. The model accounted for differences in toxic fractions between technology groups, driving cycles, and normal versus high emitters. Impacts of fuel formulations were also addressed in the modeling.

Toxic emissions were modeled for 10 urban areas and 16 geographic regions. These urban areas and geographic regions are presented in Table III.D-1. They were selected to encompass a broad range of I/M programs, fuel parameters, and temperature regimes. The intent of the selection process was to best characterize the different combinations needed to perform accurate nationwide toxic emissions estimates. Each U. S. county was then mapped to a modeled area or region. This approach was also used to develop the inventory estimates in the 1996 National Toxics Inventory.

Modeling for these areas was done on a seasonal basis. Information on fuel properties for 1990 and 1996 was obtained from surveys conducted by the National Institute for Petroleum and Energy Research (NIPER) and the American Automobile Manufacturers Association (AAMA). Fuel parameters for 2007 and 2020 were projected from 1996 baseline values using information from a February 26, 1999 report from Mathpro to the American Petroleum Institute. Data from the EPA Emission Trends Database and other agency sources were used to develop appropriate local modeling parameters for inspection maintenance programs, Stage II refueling controls, fuel RVP, average ambient temperature, and other inputs.

#### **Exhaust Emissions**

Analysis of speciation data from 1990 technology light-duty gasoline vehicles done for the EPA Complex Model for Reformulated Gasoline showed that the fraction of toxic emissions relative to TOG differs among eight technology groups within the Complex Model as well as between normal emitters and high emitters. This difference is especially significant for 1,3butadiene; its toxic/TOG fraction is about three times larger for high emitters than for normal emitters. If this difference is not taken into account, the impact of I/M programs and fleet turnover to vehicles with lower deterioration rates will be underestimated. Thus, the input format for exhaust toxic adjustment factors in MOBTOX5b was structured to allow input of high and normal emitter toxic emission rates for a given "target" fuel. The target fuel is simply the fuel of concern in the modeling analysis. These toxic emission rates were then weighted to come up with a composite toxic emission factor, based on a distribution of normal and high emitters. This distribution is not supplied directly by the MOBILE model. Instead, this distribution was determined from the fleet average TOG emission rate on baseline fuel as determined by MOBILE and average normal and high TOG emission rates on baseline fuel derived from the Complex Model. Essentially, "toxic-TOG curves" were developed that plot the target fuel toxic emission rate against the base fuel TOG emission rate.

Table III.D-1. Areas Included in Toxic Emissions Modeling

Chicago, IL	Atlanta, GA	Florida
Denver, CO	Western WA/ OR	Northeast States – non-I/M and non-RFG
Houston, TX	Northern CA	Northeast States - I/M and non-RFG
Minneapolis, MN	Southern CA	Northeast States - non-I/M and RFG
New York, NY	ID/ MT/ WY	Ohio Valley – non-I/M and non-RFG
Philadelphia, PA	UT/ NM/NV	Ohio Valley – I/M and non-RFG
Phoenix, AZ	West TX	Ohio Valley – I/M and RFG
Spokane, WA	ND/ SD/ NB/ IA/ KS/ Western MO	Northern MI/ WI
St. Louis, MO	AR/ MS/ AL/ SC/ Northern LA	

To construct these curves, the distribution of normal and high emitters was determined in the following manner for each model year. A TOG gram per mile emission rate for normal emitters (TOG-N) and a TOG emission rate for high emitters (TOG-H) on baseline fuel were input into MOBTOX5b. TOG-N from newer technology light-duty gasoline vehicles and trucks were obtained from an unconsolidated version of the Complex Model, which provides output for normal emitters in each of eight technology groups. The Complex Model provides estimates for mass of exhaust VOC, which is TOG minus the mass of methane and ethane. TOG was estimated by applying a conversion factor which accounts for the mass of these compounds. The conversion factor was derived by analysis of weight percent emissions of methane and ethane from available speciation data. Based on the distribution of technology groups in given model year, the individual TOG estimates were weighted appropriately to obtain a composite estimate for all normal emitters. Since the unconsolidated model's TOG-N emission rates are applicable only to Tier 0 light duty vehicles, they had to be adjusted for Tier 1 and later vehicles. This adjustment was performed by multiplying the unconsolidated model results by the ratio of the emission standard for these later vehicles to the Tier 0 emission standard. TOG-H was also

obtained from the unconsolidated version of the Complex Model. TOG-H was assumed to be the same for all Tier 0 and later high emitting vehicles.

For benzene, 1,3-butadiene, formaldehyde, and acetaldehyde, milligram per mile toxic emission rates for normal and high emitters running on a given fuel formulation were also entered into MOBTOX5b, using output from the unconsolidated version of the Complex Model.

An example of the data file format is provided in Table III.D-2. Using the information in the data file, an overall FTP toxic emission rate for each vehicle class in a given model year is calculated. This overall rate takes into account the distribution of normal and high emitters by calculating the slope and intercept of a straight line (the "toxic-TOG" curve), where the FTP toxic emission rates for a vehicle class in a given model year are a linear function of the baseline fuel TOG emission rate:

$$TOX_{Flt, Fuel A, FTP} = A + B*TOG_{Baseline fuel, FTP}$$
 (1)

A and B are determined as follows:

$$A = (TOG-H*TOX-N - TOG-N*TOX-H)/(TOG-H - TOG-N)$$
(2)  
$$B = (TOX-H - TOX-N)/(TOG-H - TOG-N)$$
(3)

where:

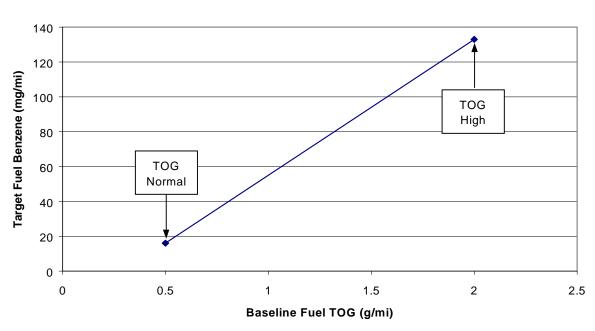
TOX-N = toxic emission rate for normal emitters derived from the Complex Model TOX-H = toxic emission rate for high emitters derived from the Complex Model

Table III.D-2. Example of Data File Format for Toxic Adjustment Factors

IV	MYA	МҮВ	TOG-N	TOG-H	BZ-N	BZ-H	AC-N	АС-Н	FR-N	FR-H	BD-N	BD-H
1	1965	1974	0.000	10.00	0.00	276.93	0.00	109.72	0.00	224.28	0.00	93.15
1	1975	1980	0.000	10.00	0.00	263.61	0.00	108.70	0.00	173.41	0.00	44.57
1	1981	1987	0.640	4.03	28.63	113.23	5.07	32.89	7.16	44.59	2.14	25.84
1	1988	1999	0.570	4.03	17.49	116.45	4.02	28.65	5.67	36.68	2.04	30.82

IV = vehicle class, MYA = initial model year, MYB = final model year, TOG-N = TOG for normal emitters running on baseline fuel in g/mi, TOG-H = TOG for high emitters on baseline fuel in g/mi, BZ = benzene in mg/mi for vehicles running on fuel A, AC = acetaldehyde in mg/mi on fuel A, FR = formaldehyde in mg/mi on fuel A, BD = 1,3-butadiene in mg/mi on fuel A

These relationships can be thought of graphically, as illustrated in Figure III.D-1, below.



# **Hypothetical Benzene-TOG Curve**

Figure III.D-1. Example Plot of Target Fuel Benzene Versus Baseline Fuel TOG under FTP Conditions

An issue related to the above methodology is whether the linear assumption is valid for baseline TOG values above the high emitter point and below the normal emitter point. This is particularly relevant in cases where A and B values are determined from Tier 0 vehicles (e.g., the Complex model), but the results are applied to Tier 1 and LEV-category vehicles. For the simple example presented above, negative benzene emissions are estimated for the target fuel when the baseline fleet-average TOG emission rate falls below 0.295 g/mi. Thus, for fleet-average emission rates below (and above) the normal (and high) emitter values, a different methodology was needed. In those cases, it was assumed that the toxic emission rate was the same on a fractional basis (for VOC emission rates below the Tier 0 normal emitter rate, for example, the toxic fraction stays constant at the toxic fraction for Tier 0 normal emitters). In the example above, the benzene emission rate for a baseline TOG value of 0.1 g/mi would be calculated as follows:

$$BZ_{(TOG=0.1~g/mi)}~=~0.1~g/mi~*(16~mg/mi~BZ~/~0.5~g/mi~TOG) = 3.2~mg/mi$$

This has the effect of forcing the toxic-TOG curve from the normal-emitter point back through the origin and thus avoids negative toxic emission rate estimates for Tier 1 and LEV-category vehicles. The same approach is used in cases where the fleet-average baseline TOG emission

rate is above the high emitter point.

For non-light duty vehicle classes and older technology light-duty vehicles, such as non-catalyst and oxidation catalyst vehicles, adequate toxic emissions data were not available to distinguish between emission rates of normal and high emitters. In such cases, the toxic fraction was assumed to be constant regardless of the VOC emission level.

Next, aggressive driving corrections were applied to the FTP toxic emission rates for light duty vehicles. These corrections were provided in an external data file and were multiplicative in form. Several recent studies suggest that toxic fractions of TOG differ between FTP and aggressive driving conditions<sup>71,72,73</sup> Thus, another adjustment to the toxic emission rates was applied to take into account this difference in toxic fractions. This adjustment took the form of the ratio of the toxic mass fraction over the unified cycle (FTP and off-cycle) to the toxic mass fraction over the FTP. The adjustment was obtained from an analysis of unpublished CARB data as described in EPA (1999d). The toxic emission rate under the unified cycle (FTP and off-cycle) was calculated in the model as follows:

$$TOX_{UC} = TOX_{FTP} * ADJ_{Aggressive Driving} * ADJ_{TOX UC/FTP}$$
 (4)

where

 $TOX_{UC}$  = Unified Cycle toxic emission rate

 $TOX_{FTP} = FTP$  toxic emission rate

ADJ<sub>Aggressive Driving</sub> = Adjustment to TOG emissions for aggressive driving

ADJ<sub>TOX UC/FTP</sub> = Adjustment for difference in toxic mass fraction over the UC versus FTP

MOBTOX5b then applies temperature, speed, humidity and load corrections.

Evaporative, Refueling, Running Loss, and Resting Loss Emissions

MOBTOX5b estimated evaporative, refueling, running loss, and resting loss toxic emissions for benzene. (1,3-Butadiene, formaldehyde, and acetaldehyde are not found in fuel and hence are not found in nonexhaust emissions. Because their nonexhaust emissions are zero, they were not included in the portions of MOBTOX5b used to estimate nonexhaust emissions.) Benzene fractions of total hydrocarbons were entered in an external data file. Separate fractions were entered for hot soak, diurnal, refueling, running loss, and resting loss. Toxic fractions for evaporative, refueling and running loss benzene from gasoline vehicles were obtained from the Complex Model (EPA 1994). The Complex Model does not estimate resting loss emissions. EPA assumed that the benzene fractions of diurnal and resting loss emissions were the same.

#### ii. Diesel PM Emissions Modeling

To estimate diesel PM emissions, we used EPA's PART5 model. PART5 is similar in structure and function to the MOBILE series of models. It calculates exhaust and non-exhaust (e.g., road dust) particulate emissions for each vehicle class included in the MOBILE models. Only primary exhaust PM emission rates from diesel vehicles were included in these analyses since cancer potencies are not available for PM emissions such as tire and brake wear or for secondary PM formed through transformation of diesel engine emissions of SOx, NOx, and VOC. A particle size cut-off of  $10~\mu m$  was specified in the model inputs since essentially all primary exhaust PM from diesel engines is smaller than  $10~\mu m$ .

Diesel PM emission estimates are not presented in this section of the RIA since the impact of this rulemaking on the diesel PM inventory is discussed in Section III.A.4. It should be noted, however, that the diesel PM exposure estimates presented herein were based on inventory numbers developed in a slightly different manner than the ones in Section III.A.4. To develop these inventory estimates, we modeled emission factors in 26 areas explicitly and then mapped the remaining U. S. counties to these modeled areas, as described in Section III.D.2.a.i. The resulting emission factors for each county were multiplied by VMT estimates from EPA's Trends database to obtain total mass emissions estimates. The 2007 and 2020 light-duty diesel PM emission estimates obtained using this approach were within about 15 percent of the estimates presented in III.A.4 for all scenarios modeled.

#### b. Nationwide Toxic Emissions Estimates – Baseline Scenario

Toxic emission factor estimates for each county in the United States were developed by mapping them to one of the modeled areas (EPA, 1999d). The resulting county level emission factors were multiplied by VMT estimates from EPA's Emission Trends database to come up with nationwide emissions in tons. Forty-seven state estimates for gaseous toxics under baseline scenarios in 1990, 1996, 2007, and 2020 are given in Table III.D-3;<sup>26</sup> the diesel particulate estimates can be found in or inferred from Table III.A-11 for current diesel penetration rates and Table III.A-15 for increased diesel penetration rates. The baseline scenario assumed implementation of NLEV standards (0.09 g/mi) for light-duty gasoline vehicles and light duty trucks under 6000 lbs. gross vehicle weighting, Tier 1 standards for light-duty trucks over 6000 lbs., and a mix of conventional gasoline and Phase 2 reformulated gasoline with no additional sulfur control.

<sup>&</sup>lt;sup>26</sup>Diesel PM inventory estimates are presented elsewhere in the Regulatory Impact Analysis.

Table III.D-3. 47 State Highway Vehicle Toxic Emissions (tons) In 1990, 1996, 2007, and 2020, for Baseline Scenarios.

Toxic	CY 1990	CY 1996	CY2007	CY2020
Benzene	228,000	156,000	89,000	81,000
Acetaldehyde	37,000	25,000	14,000	14,000
Formaldehyde	126,000	72,000	34,000	34,000
1,3-Butadiene	33,000	21,000	12,000	12,000

## c. Exposure – Baseline Scenario

Exposure modeling was done for 1990 using the Hazardous Air Pollutant Exposure Model for Mobile Sources, Version-3, or HAPEM-MS3. T4, T5 Data from 10 urban areas were used. These areas were Atlanta, GA, Denver, CO, Houston, TX, Minneapolis, MN, New York, NY, Philadelphia, PA, Phoenix, AZ, Spokane, WA, and St. Louis, MO. HAPEM-MS3 uses CO as a tracer for toxics. Since most ambient CO comes from cars and light trucks, we believe CO exposure is an reasonable surrogate for exposure to other motor vehicle emissions, including toxics emissions. The HAPEM model links human activity patterns with ambient CO concentration to arrive at average exposure estimates for 22 different demographic groups (e.g., outdoor workers, children 0 to 17, working men 18 to 44, women 65+, etc.) and for the total population. The model simulates the movement of individuals between home and work and through a number of different microenvironments. The CO concentration in each microenvironment is determined by multiplying ambient concentration by a microenvironmental factor.

With the 1990 CO exposure estimates generated by HAPEM model for each urban area, EPA determined the fraction of exposure that was a result of on-road motor vehicle emissions. This calculation was accomplished by scaling the exposure estimates (which reflect exposure to total ambient CO) by the fraction of the 1990 CO emissions inventory from on-road motor vehicles, determined from the EPA Emission Trends database. Nationwide urban CO exposure from on-road motor vehicles was estimated by first calculating a population-weighted average CO exposure for the ten modeled areas. This number was adjusted by applying a ratio of population-weighted annual average CO for urban areas in the entire country versus average ambient CO concentration for the modeled areas. To estimate rural exposure, the urban estimate was scaled downward using rough estimates of urban versus rural exposure from the 1993 *Motor Vehicle-Related Air Toxics Study* (EPA 1993a).

Modeled onroad CO exposure for 1990 was divided by 1990 CO grams per mile emission estimates to create a conversion factor. The conversion factor was applied to modeled toxic emission estimates (in grams per mile terms) to determine exposure to onroad toxic emissions, as shown in Equation 6:

$$TOX_{Exposure(\mu g/m3)} = [CO_{Exposure(\mu g/m3)}/CO_{EF(g/mi)}]_{1990} \times TOX_{EF(g/mi)}$$
(6)

where TOX reflects one of the six toxic pollutants considered in this study.

The exposure estimates for calendar years 1996, 2007, and 2020 were adjusted for VMT growth relative to 1990. In the baseline scenario, we did not assume any increased penetration of diesel engines into the light-duty fleet. 1,3-Butadiene exposure was adjusted for atmospheric transformation. The multiplicative factors used were 0.44 for summer, 0.70 for spring and fall, and 0.96 for winter. These factors account for the difference in reactivity between relatively inert CO, which is being used as the tracer for toxics exposure, and 1,3-butadiene. In contrast, estimated exposure to formaldehyde and acetaldehyde was based on direct emissions. For these pollutants, removal of direct emissions in the afternoon was assumed to be offset by secondary formation. Table III.D-4 presents annual average exposure estimates for the entire population. Estimates were also developed for outdoor workers, and children 0 - 17 years of age. Exposure among outdoor workers was higher than for the entire population, and among children it was slightly lower.

Table III.D-4. Average 47 State Highway Vehicle Toxic Exposure (μg/m³) In 1990, 1996, 2007, and 2020, for Baseline Scenarios.

Toxic	CY 1990	CY 1996	CY2007	CY2020
Benzene	0.99	0.68	0.39	0.35
Acetaldehyde	0.16	0.11	0.06	0.06
Formaldehyde	0.54	0.32	0.15	0.15
1,3-Butadiene	0.11	0.07	0.04	0.04
Diesel PM	0.78	0.44	0.25	0.27

It should be noted that recent California-EPA studies estimated a population-weighted average outdoor diesel exhaust  $PM_{10}$  (particulate matter <  $10~\mu m$ ) exposure for  $1995.^{79}$  California also estimated indoor and total exposure concentrations for 1995. The 1995 indoor and total air exposure concentrations were estimated to be  $1.47~\mu g/m^3$  and  $1.54~\mu g/m^3$ , respectively. This estimate compares to the estimated annual average 47 State highway diesel  $PM_{10}$  1996 exposure estimate of  $0.44~\mu g/m^3$  in Table III.D-4. One significant reason for the difference is that the California estimate is for diesel  $PM_{10}$  from all sources, including nonroad while the estimate in Table III.D-4 is only for highway vehicles. Other reasons may be differences in estimates of emission rates, exposure patterns, the concentration of diesel vehicle traffic, or the spatial distribution of diesel engine emissions.

## d. Impact of Potential Vehicle and Fuel Controls

The following control scenarios for 2007 and 2020 were assessed:

- base fuels and emissions with NLEV and a 30 ppm sulfur standard.
- NLEV, 30 ppm sulfur, and Tier 2 tailpipe standards
- NLEV, 30 ppm sulfur, Tier 2 tailpipe standards, and increased diesel penetration

Estimates of the impact of VOC reductions from Tier 2 tailpipe standards for the full useful life of the vehicle, combined with a 30 ppm sulfur standard, on toxics emissions and exposure, are provided in Tables III.D-6 through III.D-9.

The current updated assessment also evaluated the potential increase in diesel PM emissions and exposure due to increased use of diesel engines in cars and light trucks. Diesel engines are used in a very small portion of the cars and light-duty trucks in service today. However, engine and vehicle manufacturers have projected that diesel engines are likely to be used in an increasing share of cars and light trucks. Some manufacturers have announced capital investments to build such engines. The impact of this increase in light of Tier 2 standards were evaluated. For our projections through 2015, we assumed the most likely level of increased diesel penetration modeled in a draft report prepared by Arthur D. Little, Inc. for the American Petroleum Institute. For years subsequent to 2015, we assumed that diesel engines' share of vehicle sales would continue to grow at the rate projected for 2010 through 2015 in the Arthur D. Little most likely scenario.

This assumption differs from that used to project the potential impact of greater diesel sales on PM emissions from cars and light trucks found in Section A.4.b of this chapter, where diesel engines' share of car and light truck sales were held constant at 2015 levels for subsequent years. The difference in these projections stems from their different purposes. The projections in Section A.4.b represent our efforts to project the impact of a likely diesel engine sales scenario on PM emissions. The projections used for the diesel PM analysis described in this section are

designed to illustrate the potential for greater diesel engine use in cars and light trucks to increase the health risks associated with diesel PM; they represent a more speculative scenario and should be used to evaluate the potential (rather than the most likely) impact of greater diesel engine use on the unique health risks associated with diesel PM. The sales penetration rates for this cautionary scenario are presented in Table III.D-5.

Table III.D-5. Percentage of sales fleet expected to be diesel in each respective year under "most likely" scenario, as estimated in A. D. Little, Inc. report.

Vehicle Class	2000	2005	2010	2015	2020
LDV	0	0	2	9	16
LDT1	1	3	17	22	27
LDT2	0	0	12	17	22
LDT3	2	13	23	30	37
LDT4	3	14	23	31	39

The impact of such increased diesel penetration on exposure to diesel PM are provided in Tables III.D-8 and III.D-9. Based on the exposure estimates for 2020 under Tier 2 controls, the potential 47 State cancer risk from diesel particulate matter would increase by about 8 percent under this scenario. Beyond 2020, the health risks would be even greater for two reasons. First, the proportion of cars and light trucks equipped with diesel engines would continue to increase as the older, gasoline-powered cars and light trucks are replaced by a mix of gasoline and diesel cars and light trucks. Second, continued growth in the total number of miles driven would increase diesel PM emissions. It should be noted that without Tier 2 controls, we estimate that the increased presence of diesel-powered cars and light trucks on the nation's roads could increase the potential cancer risks associated with PM emissions from all diesel-powered highway vehicles (including heavy-duty diesel trucks, diesel buses, and light-duty diesel vehicles) by approximately 80 percent as of 2020. This estimate is based on an inventory of about 69,000 tons of diesel PM from all highway vehicles in 2020 without increased diesel penetration, versus about 125,000 tons with increased diesel penetration. The 80 percent increase in inventory likely would translate into a similar increase in cancer risk.

Table III.D- 6. 47 State Highway Vehicle Toxic Emissions (tons) in 2007, for Various Scenarios

Toxic	No New Controls Scenario	30 ppm Sulfur Scenario	Tier 2 Standard w/30 ppm Sulfur Scenario	Tier 2 Standard, 30 ppm Gasoline Sulfur, & Increased Diesel Sales Scenario
Benzene	89,000	82,000	80,000	78,000
Acetaldehyde	14,000	13,000	13,000	13,000
Formaldehyde	34,000	33,000	32,000	33,000
1,3-Butadiene	12,000	11,000	11,000	10,000

Table III.D-7. 47 State Highway Vehicle Toxic Emissions (tons) in 2020, for Various Scenarios

Toxic	No New Controls Scenario	30 ppm Sulfur Scenario	Tier 2 Standard w/30 ppm Sulfur Scenario	Tier 2 Standard, 30 ppm Gasoline Sulfur, & Increased Diesel Sales Scenario
Benzene	81,000	74,000	63,000	55,000
Acetaldehyde	14,000	13,000	12,000	12,000
Formaldehyde	34,000	33,000	30,000	30,000
1,3-Butadiene	12,000	11,000	10,000	9,000

Table III.D-8. Average 47 State Highway Vehicle Toxic Exposures for the Entire Population ( $\mu g/m^3$ ) in 2007, for Various Scenarios

Toxic	No New Controls Scenario	30 ppm Sulfur Scenario	Tier 2 Standard w/30 ppm Sulfur Scenario	Tier 2 Standard, 30 ppm Gasoline Sulfur, & Increased Diesel Sales Scenario
Benzene	0.39	0.39	0.35	0.34
Acetaldehyde	0.06	0.06	0.06	0.06
Formaldehyde	0.15	0.15	0.14	0.15
1,3-Butadiene	0.04	0.03	0.03	0.03
Diesel PM	0.25	0.25	0.25	0.28

Table III.D-9. Average 47 State Highway Vehicle Toxic Exposures for the Entire Population ( $\mu g/m^3$ ) in 2020, for Various Scenarios

Toxic	No New Controls Scenario	30 ppm Sulfur Scenario	Tier 2 Standard w/30 ppm Sulfur Scenario	Tier 2 Standard, 30 ppm Gasoline Sulfur, & Increased Diesel Sales Scenario
Benzene	0.35	0.32	0.27	0.24
Acetaldehyde	0.06	0.06	0.05	0.05
Formaldehyde	0.15	0.14	0.13	0.13
1,3-Butadiene	0.04	0.03	0.03	0.03
Diesel PM	0.27	0.27	0.26	0.29

#### E. Carbon Monoxide

The standards being promulgated today will help reduce levels of carbon monoxide (CO). Twenty areas, with a combined population of 33 million, are designated as being in nonattainment with the CO NAAQS. An additional 24 areas with a combined population of 22 million are designated as CO maintenance areas. In 1997, 6 of 537 monitoring sites reported ambient CO levels in excess of the CO NAAQS.

As discussed in Section III.A, the Tier 2/Sulfur standards will require light trucks to meet more stringent CO standards. These more stringent standards will help extend the trend towards lower CO emissions from motor vehicles and thereby help the remaining CO nonattainment areas reach attainment while helping other areas remain in attainment with the CO NAAQS. The analysis of economic benefits and costs found in Section IV.D.-5. does not account for the economic benefits of the CO reductions expected to result from today's proposal.

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